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MASSACHUSETTS AGRICULTURAL COLLEGE

THIRTY-FIFTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Parts I and II

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THIRTY-FIFTH ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

PART I

REPORT OF THE DIRECTOR AND OTHER OFFICERS

PART II

DETAILED REPORT OF THE EXPERIMENT STATION

BEING PARTS III AND IV OF THE SIXTIETH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL COLLEGE

A RECORD OF THE FORTIETH YEAR FROM THE FOUNDING OF THE STATE AGRICULTURAL EXPERIMENT STATION

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REPORT OF THE DIRECTOR.

SIDNEY B. HASKELL.

REVIEW OF THE YEAR.

Additions to Station Equipment.

Through appropriation made by the legislature, the Station this past year was able to supplement its land equipment through the purchase of the farm lying immediately north of its present area. By the vote of the trustees of the College this is to be known as the "William P. Brooks Experimental Farm". It contains about sixty acres of land, most of this being tillable and admirably adapted for experimental work, particularly in the two great crops of the Connecticut Valley — onions and tobacco. It is a cause for gratification that the legislature realized the need, for existing facilities have been taxed to the utmost.

In addition to the above there is promise of improvement in the Station land equipment in one other direction, this coming about through the offer from the trustees of the will of the late Miss Cornelia Warren of some fifty acres of land in Waltham, for the uses of the College. The trustees of the College have voted to accept the gift and have placed this in the custody of the Experiment Station in expectation of moving the Market Garden Field Station from Lexington to the new estate in Waltham. This area has two distinct soil types, both of them relatively uniform and typical of fairly large areas, and is in many other ways better suited for experimental work in vegetables than is our present location. At the date of making this report the transfer has not yet been finally made, nor has the project been approved by the legislature. It is to be hoped, however, that the change may be made without difficulty.

The land equipment of the Station may now be considered as complete, save only for two minor projects: the first relating to the purchase of a small area to supplement the equipment of the Cranberry Station; the second of land devoted to pasture experimental work. This last is important to the welfare of the dairy industry; and as soon as land now under the control of the Station is developed for experimental purposes, the project will be formally presented.

Changes in Organization Policy.

During the year a number of changes in administrative policy have been made, all of these with the objective of securing greater economy. Through arrangements with the treasurer's office, much of the labor of accounting is now removed from the Station office. The mailing lists of Extension Service and Station are now combined, with the work done by the former organization. This is a distinct step in advance, prevents duplication of effort, and through centralization insures lower cost of handling the Station publications. In the publication work itself the size of editions has been greatly reduced, and bulletins are now sent out to but restricted mailing lists or on request only. This eliminates waste circulation and insures, so far as may be possible, maximum returns from publication funds available. Finally, for much of the miscellaneous analytical work formerly done, a charge is now being made for that part which is primarily personal service. Despite the fact that the practice of making free analyses of agricultural products is a custom of long standing, this change has been put into effect with an astonishingly small amount of criticism. The soundness of the Station position, that its funds must be expended for the benefit of the people in general rather than for the individual, seems to be generally accepted.

Changes in Staff.

Dr. H. D. Goodale, for nearly ten years in the service of the Department of Poultry Husbandry, resigned June 30, 1922, on account of ill health. Dr. Goodale came to the Station from the Carnegie Laboratory, Cold Spring Harbor, New York, and brought to the Department of Poultry Husbandry the service of a man trained primarily in biology and genetics. Despite the most discouraging conditions which have attended his work, particularly the inability to control diseases on account of deficiencies in land equipment and inability to maintain quarantine, Dr. Goodale made consistent and continuous progress in his breeding work. At the time of his leaving the Station, he had developed a flock of Rhode Island Reds from which broodiness had been largely eliminated, which was early maturing, which laid heavily in winter, and which finally had given an average of 200 eggs per bird as the annual production. It was with very great regret that Dr. Goodale's resignation was accepted.

The position of Research Professor of Poultry Husbandry has been filled by the appointment of Dr. Frank A. Hays, who entered on his duties September 28, 1922. Dr. Hays comes to the institution after service in Delaware, Iowa and Wyoming. He has already had a large amount of experience in research work of this kind.

On October 5, 1922, Dr. James B. Paige, for sixteen years head of the Department of Veterinary Science in the Station, passed away. Dr. Paige had been associated with this Station since its earlier years, and had always given most valuable service. Alike for his thoroughgoing honesty and his sound common sense, Dr. Paige will be sorely missed.

The position of Professor of Animal Pathology has been filled by the appointment of Dr. George Edward Gage, who is likewise head of the Department of Veterinary Science and Animal Pathology.

On October 1 Dr. John B. Lentz was transferred from the position of Assistant Research Professor of Veterinary Science to full-time member of the teaching staff, and Veterinarian of the College. In this position Dr. Lentz' training and experience will still be available to the Station. The position of Assistant Research Professor of Avian Pathology has been created in place of that held by Dr. Lentz, and filled by the appointment of Dr. Norman J. Pyle, a graduate of the University of Pennsylvania.

In the Control Service there have been a number of changes. Miss Ethel M. Bradley resigned July 15, 1922, as Analyst, with the position filled by the appointment of Mr. Frank J. Kokoski. Mr. Ray A. Carter resigned in June, 1922, as Collector of Blood Samples under the Poultry Disease Elimination Law, with the position filled by the appointment of Mr. John J. Smith. Under date of September 30, Miss Ann Smith, Analyst in the same service, resigned, with the position filled by the appointment of Miss Mildred H. Hollis.

During the year the title of Miss Sanborn, Clerk in the Department of Poultry Husbandry, was changed to Investigator.

By action of the board of trustees, the Departments of Agronomy, Animal Husbandry, Dairy Manufactures, Farm Management and Rural Engineering were recognized as Station departments, with the heads of these departments members of the Station staff.

Publications of the Year.

Annual Report.

Thirty-fourth annual report:
- Part I. Report of the Director and Other Officers; 79 pages.
- Part II. Detailed Report of the Experiment Station; 168 pages (Bulletins 201–206).
- Combined Contents and Index, Parts I and II; 20 pages.

Bulletins.

No. 207. Injury to Foliage by Arsenical Sprays. I. The Lead Arsenates, by H. T. Fernald and A. I. Bourne; 20 pages.
No. 208. Leaf Characters of Apple Varieties, by J. K. Shaw; 12 pages.
No. 209. Experiments in Soil Management and Fertilization of Orchards, by J. K. Shaw; 28 pages.
No. 210. Injury to Foliage by Arsenical Sprays. II. Calcium Arsenates and Arsenites. III. Notes on Other Arsenicals, by H. T. Fernald and A. I. Bourne; 10 pages.
No. 211. Changes in Egg Production in the Station Flock, by H. D. Goodale and Ruby Sanborn; 28 pages.
No. 212. A Thirty-Year Fertilizer Test, by Sidney B. Haskell; 32 pages.

Bulletins, Technical Series.

No. 5. Concerning the Diagnosis of *Bacterium pullorum* Infection in the Domestic Fowl, by George Edward Gage; 28 pages.

Bulletins, Popular Edition.

No. 211. Changes in Egg Production in the Station Flock, by H. D. Goodale; 8 pages.

Bulletins, Control Series.

No. 18. Control of Bacillary White Diarrhœa, 1920–1921, by G. E. Gage, 8 pages.
No. 19. Inspection of Commercial Feedstuffs, by Philip H. Smith and Ethel M. Bradley; 34 pages.
No. 20. Inspection of Commercial Fertilizers, by H. D. Haskins, L. S. Walker, and R. W. Swift; 42 pages.
No. 21. Inspection of Lime Products Used in Agriculture, by H. D. Haskins, L. S. Walker and R. W. Swift; 8 pages.
No. 22. Control of Bacillary White Diarrhœa, 1921–1922, by G. E. Gage and O. S. Flint; 8 pages.

Meteorological Reports.

Nos. 397–408, inclusive, 4 pages each.

Control Activities.

Through State law, four different control activities are now being operated and administered by the Station: these being the feed and fertilizer control laws, the law for the inspection of dairy glassware, and the poultry disease elimination law. Reports on the first two activities have been published in Control Bulletins Nos. 19, 20 and 21, and that of the poultry disease elimination law in Control Bulletin No. 22. Since these reports give full details of the operations in 1922, no further mention need be made in this place. The activities under the law for the inspection of dairy glassware are similar to those of preceding years.

In addition to the above, the Station also administers the advanced registry testing work for several different breed associations. This is operated as a trust fund, the work being billed at cost plus ten per cent to allow for overhead. This fund now pays the salary of a full-time assistant, who cares for the routing of the men, keeping of the records, and other work of this nature. The Experiment Station acts only as a neutral, disinterested party for determining certain stated facts. It guarantees nothing other than the accuracy of records taken under its immediate supervision.

Extension Phases of Station Work.

As in previous years the time of several of the Station men, available for research work, is seriously diminished by calls for extension service. This is particularly the case in the Department of Veterinary Science, which in the spring of the year receives numerous calls for examination of dead chicks and dead fowl. In the Department of Botany many calls come for diagnostic service on plant diseases; and in the Department of Entomology, for similar service in respect to injurious insects. Work of this sort is essential and is not duplicated by any existing commercial organization. It is probably impossible, or if not impossible at least impracticable, to divorce investigational work entirely from educational work of this character. It should be recognized, however, that diagnosis and analysis serve only as means to the end of improvement in certain directions. As a matter of institutional policy, it is probable that, as soon as work of this kind develops so as to be a serious drain on our investigational forces, it should be organized under the Extension Service. This need is recognized by the Extension Service, and will be met as soon as funds are available.

Co-operative Organization of Extension Demonstration Projects.

Since the Station finds it necessary to do some extension work, it follows at once that a certain amount of research work, at least of fact-finding work of a survey type, may have to be done by our Extension forces. This has been particularly the case in the field of farm management, and the technical subjects of agronomy, pomology, vegetable gardening and poultry husbandry. The field demonstrations operated by some of these departments should give valuable data worthy of permanent preservation. This value, however, depends always on the authority back of the records taken. In order that this work may be better done, and to insure preservation of such records as have value, some of these demonstrations have been organized in the Station as co-operative projects. The leader of these projects must make himself responsible for the accuracy of the work. Unless he can vouch for the records presented they cannot be accepted. It is too early as yet to speak of the success or failure of this plan. There are, however, seven projects organized on this basis, as follows:

"Poultry disease prevention and eradication"	Extension Professor Monahan.
"Artificial illumination of poultry"	Extension Professor Monahan.
"The use of nitrate of soda in apple orchards"	Extension Professor Van Meter.
"Controlling peach borers"	Extension Professor Van Meter.
"Thinning apples"	Extension Professor Van Meter.
"Comparison of results obtained in spraying with spray rod and spray gun"	Extension Professor Van Meter.
"Investigation of farm organization and labor efficiency on Massachusetts farms"	Professor Foord.

In addition to the above there are two other co-operative projects in which the expenses are met by the Station, but the salaries paid from other funds. One of these is the "Boston food supply study" carried out under the leadership of Dr. McFall; the other, "Testing low lift pumps" with the work done by the members of the Department of Rural Engineering under the leadership of Professor Gunness. These two projects are recorded in the reports on our investigational service.

REPORT ON PROJECTS.

Plant Nutrition and Soil Fertility.

The problem of soil fertility is dominant in every agriculture. It becomes more difficult as soils become older and agriculture becomes more intensive — and Massachusetts soils are old soils, and its agriculture is becoming more and more intensive. Orcharding, vegetable gardening, specialty vegetable growing such as asparagus growing or onion production, tobacco culture, cranberry culture — these are typical of the agricultural activities developing in the State. The fertility problems incident to the growing of these crops differ very greatly from those of the general farm. But even on the livestock farm there are some difficult problems, particularly on our permanent pastures. For all of these reasons, therefore, it is but natural and normal that a very large part of the Station resources should be used in the study of soil fertility and plant nutrition problems. These various projects group themselves into three major classes: (1) fundamental problems of the soil and plant, studied through the Departments of Botany and Plant and Animal Chemistry; (2) problems in fertility practice, studied through the Departments of Agronomy, Pomology, the Cranberry Station and the Market Garden Field Station; and (3) investigation into the nature and value of fertilizer materials, carried out in conjunction with the Fertilizer Control, through the Department of Agriculture.

A complete list of fertility and nutritional projects under way follows, together with a brief report of progress during the past year.

Chemical Investigations.

Chemistry Project 6. "Lime absorption and acidity of Field A."
Professor Morse and Assistant Professor Jones.

The numerous analyses of the drainage waters from the plots of this field have been co-ordinated, and have been found to give consistent results which show that the use of ammonium sulfate exhausts the calcium carbonate much more rapidly than is the case where no nitrogen has been applied, while sodium nitrate removes less calcium carbonate than either treatment. This is true at all seasons of the year when water has flowed from the drains. Determinations of residual calcium carbonate in the soils of the different plots corroborate results from study of the drainage waters. Calcium carbonate is more abundant in the soil which has received sodium nitrate than in that with no nitrogen treatment, while it is lowest in the soil that has received ammonium sulfate. The cause is due partly to the character of the chemical and partly to the difference in amount of nitrification induced in the soils.

Chemistry Project 7. "Effect of sulfate and muriate of potash on the soils of Fields A and B."
Professor Morse and Assistant Professor Jones.

The work on winter injury of brambles is directly connected with this project.

Analyses of twigs and canes from currants, gooseberries and blackberries which have grown on soils fertilized with one or the other of the two potash salts have resulted in some evidence that there is a difference in composition produced by the different fertilizers. The proportion of sugar has been consistently lower in the wood of the various plants grown on the muriate treated plot. Starch and pentosans are not so consistent, which is possibly due to two causes: the actual differences in these constituents may not really be very wide; the methods for their determination are much more approximate than those for sugars. A qualitative comparison of the chlorine present in the ash of the two series of crops shows a much more pronounced test for the element in the series on muriate. This shows an actual absorption of chlorides.

It is fitting to remark here that the work so far can be regarded only as exploratory in character.

Chemistry Project 14. "A study of the availability of soil potash, with the object of developing a system of diagnosis for soils of the State."
Professor Morse.

Pot experiments were conducted by Mr. Coffin with similar results in growth to those obtained last year. Analyses of the crops have not yet been made.

Microbiological Investigations.

Microbiology Project 2. "Soil fertility as influenced by micro-organisms in their relation to the presence and disappearance of organic matter."
Assistant Professor Itano and Mr. Sanborn.

Several phases of this problem have already been worked out. Two papers were presented at the annual meeting of the Society of American Bacteriologists, and may be found in the following sources of information:

1. "A Micro Electrometric Method for Determination of CO_2." Abstracts of Bacteriology, V, 1, 1921, p. 5.
2. "Influence of Vitamin and Nucleic Acid on Azotobacter." Abstracts of Bacteriology, VI, 1, 1922, p. 16.

One other paper has been prepared: "The Relation of Hydrogen Ion Concentration to Azotobacter Chroococcum, Beijerinckii and Vinelandii." This was carried out in co-operation with Professor U. Yamagata of the Imperial University of Tokyo, Japan.

The work now in progress includes:

1. A study of the influence of various cover crops on Azotobacter.
2. Study of the enzymes of Azotobacter.
3. A study of the influence of various ions on Azotobacter.

In addition, the study of microbial decomposition of cellulose has been developed as far as time permits, and now includes a physiological study of the organisms isolated, and of the rate of decomposition under various conditions.

Physiological Studies.

Botany Project 1. "Optimum conditions of light for plant response."
Assistant Professor Clark.

The work under this project is conducted in field, greenhouse and laboratory. In the field, various crops have been grown under three different light intensities: (1) normal light; (2) light reduced in intensity by one layer of cheesecloth; (3) light reduced by two layers of cheesecloth. The object is to determine whether the light factor has any decided influence on the production of seed and on the growth and vigor of resulting seedlings. Seeds and tubers produced this year will be planted next year under normal and modified light conditions. Plants of the biennial type are in storage and will be replanted next year for seed production under the same light conditions in which they were grown this year. Immediate as well as cumulative effect of light intensity is under study in this phase of the work. The field space devoted to the project was considerably enlarged this year.

In the study of the influence of ultra-violet light on plant growth, little of consequence has developed. A new type of glass which absorbs both heat and the ultra-violet rays has been obtained and is being used in this work.

Study of the effect of red light in the stimulation of photosynthesis is also in progress.

Botany Project 15. "A study of plant stimulation by formaldehyde."

This project is temporarily suspended owing to changes in the staff.

Pomology Project 1. "Study of the interrelation of stock and scion in apples."
Professor Shaw.

This project was begun in 1912, and the main orchard set in 1915 and 1916. It is too early as yet to make even a progress report on this work.

Pomology Project 12. "Apple variety fruit spur study."
Professor Shaw and Assistant Professor Drain.

Certain phases of this general study have been taken over by Professors Mack and W. K. French. The former has studied the spur bearing habits of several standard varieties of apples, while the latter has investigated the effect of fertilizers on growth and fruit spur formation. Spur samples collected during the summer of 1921 are still awaiting analysis.

Pomology Project 14. "Winter injury of brambles."
Professor Shaw, Professor Morse and Assistant Professor Clark.

This project, co-operative between the Departments of Botany, Chemistry and Pomology, was organized to investigate the cause of the winter-killing of brambles as apparently brought about by differential fertilization with potash salts. See report on Chemistry Project 7, page 7a.

Samples of wood growth were taken in the autumn of 1921 from the two potash plots and analyses have been made. Pentozan determinations by the furfurol method failed to indicate a higher content on the hardier plants from the sulfate plots. Studies by Professor Clark on herbaceous plants gave negative results.

Soil Management and Fertilizer Tests.

Agriculture Project 1. "Comparison of nitrogenous fertilizers."
Assistant Professor Gaskill.

This field has the longest continuous history of any now in the control of the Experiment Station. Unfortunately, however, three plots have had to be discontinued, namely, the two which received nitrate of soda as the source of nitrogen, and the one treated annually with barnyard manure. The proximity of the new chemical laboratory may, indeed, make it necessary to discontinue the whole project.

Agriculture Project 3. "Residual value of excess phosphate applications."
Assistant Professor Gaskill.

In the project attempt is being made to utilize reserves of phosphoric acid built up in the soil from past fertilizer treatment. During the season just past, the crop of hay produced on residual phosphorus was so nearly like that on the area having current applications, as to indicate rather marked utilization of phosphoric acid reserves.

Agriculture Project 4. "Methods of applying lime, and quantity of application."
Assistant Professor Gaskill.

No crop was produced on this field during the season just past, owing to the failure of the alfalfa seeding on account of wet weather.

Agriculture Project 6. "Top-dressing permanent grasslands."
Assistant Professor Gaskill.

The crop of 1922 is the second in this test. The experiment will be discontinued after the 1923 crop is harvested, as it should then be possible to estimate the cost of bringing back "run-out" mowings through resort to commercial fertilizer top-dressing rather than to plowing and reseeding.

Agriculture Project 7. "An attempt to restore productive fertility to worn-out and maltreated soils."
Assistant Professor Gaskill.

The use of a ton per acre of a complete fertilizer of an approximate 5–8–8 grade gave marked results in the second year of an attempt to "bring back" land which had reached the lowest level of infertility. The crop was mangels, late sown. On land which had become so poor as to give scarcely more than five bushels of corn to the acre, the yield was 18 tons; while where the land had received manure every year for thirty years, the yield was only 20 tons. On land unfertilized and unmanured for thirty years, crops of 12 to 15 tons were secured.

Botany Project 13. "Ecological study of pasture vegetation."
Professor Osmun and Director Haskell.

The use of chemical fertilizers and lime on areas of an old permanent pasture badly infested with running cinquefoil and with moss resulted in a rapid change of the predominant vegetation to white clover. The combination of potash and phosphoric acid was most effective, although maximum effect was not obtained without the use of lime applied as a top-dressing. Thus far it has been impossible to measure the effect of nitrogen. The precise relationship between the occurrence of certain plants and nutrient conditions as influenced by artificial treatments has not yet been developed.

This investigation is now being enlarged to measure the results of treatments and also the effect, if any, of treatments applied at different times, particularly in late fall or winter.

Market Garden Field Station Project 1. "Manure economy tests."
Professor Tompson.

The progress of this work, developed as it was to find an answer to the problem raised by increasing shortage of animal manures, indicates that the amount of manure ordinarily used by vegetable gardeners may be cut in half, the difference being made up by chemical fertilizers, without loss of crop and in some cases with significant decrease in cost of production.

Market Garden Field Station Project 5. "Growth control by means of intercropping."
Professor Tompson.

This project represents an attempt to better the condition of soils given up to permanent onions, through the systematic use of inter-sown cover crops. The records of the year were spoiled, however, because of attack of the onion maggot and the resultant spotted stand.

Pomology Project 5. "Comparison of cultivation and sod mulch in a bearing orchard."
Professor Shaw and Mr. French.

This project, started in the spring of 1921, attempts to find the difference in effects on growth and production between cultivation in a bearing orchard and the use of nitrate of soda in conjunction with a sod mulch. The sod plots were seeded to grass in June, and the application of nitrate of soda was reduced from 300 to 150 pounds per acre. The percentage of bloom was taken on all trees and the percentage of set on certain trees of each variety and treatment, as well as the regular growth and yield records. The trees on the areas seeded to grass (to which nitrate of soda was applied) on the whole bloomed heavier, set a little better and yielded considerably more than the trees in the cultivated plots (which received no nitrate of soda). The grass sod can hardly be expected to show any pronounced effect before the 1924 crop.

Pomology Project 6. "Comparison of clover and grass in a sod mulch orchard."
Professor Shaw and Mr. French.

The trees in the sod mulch plot receiving nitrogen have already shown the influence of the fertilizer. Up to date there are no clover residues on the potash and phosphoric acid plot which could have had effect comparable with that of applied nitrogen. It is interesting to note that under the proposed comparative treatments, that is grass plus nitrogenous fertilizer on the one hand as compared to clover with potash and phosphoric acid on the other, the latter system is handicapped at the very start.

Pomology Project 7. "Test of fertilizers in a sod mulch orchard."
Professor Shaw and Mr. French.

This orchard was seeded to grass in the fall of 1921, and the fertilizer application of 1921 repeated this year. While no effect of the fertilizer could be seen last year, there was a marked response by the trees on all the fertilizer plots this year as indicated by darker leaf color than that of the check trees. The regular records of growth, bloom and yield have been taken.

Pomology Project 8. "Test of cover crops for apple orchards."
Professor Shaw and Mr. French.

This project has been continued as last year, using the same cover crop with similar results. Timothy and redtop mixture was so promising that it was used in two of the larger orchards to try it out on a more extensive scale.

Pomology Project 15. "Orchard fertilization."

Professor Shaw.

The records of this orchard for thirty years, together with those of the Graves Orchard in South Amherst, have been studied and published in Bulletin No. 209. The new schedule of fertilizer applications has been continued and the usual records taken. The Rhode Island Greening trees bloomed heavily but there was a light set. The Baldwins, on the other hand, set heavily from a sparse bloom. The yield from the check plot was very light, due to a combination of light bloom, poor set and small fruit.

Pomology Project 16. "Test of different amounts of nitrate of soda."

Professor Shaw and Assistant Professor Drain.

The regular fertilizer applications have been made, and growth and yield records taken.

Pomology Project 20. "Test of fertilizers for pears."

Professor Shaw.

While the apple and pear are closely related botanically, it does not necessarily follow that they require the same fertilizer program. A pear orchard about six years old and about an acre in area, growing in sod, was divided into three parts in the spring of 1922. One part received nitrate of soda at the rate of 300 pounds per acre; the second part, a complete fertilizer of 300 pounds nitrate of soda, 300 pounds acid phosphate and 200 pounds sulfate of potash per acre; while the third part remained without fertilizer as a check. There was a prompt nitrogen response by the grass, but the trees showed slight if any response as indicated by leaf color. Growth and yield records of individual trees are kept as in other blocks.

Pomology Project 19. "Study of the effects of fertilizer limitation on fruit plants."

Professor Shaw.

The field known as the North Soil Test field, which has had a continuous history of over thirty years, has been set aside for work with fruit plants and was planted in the spring of 1922 to apples, peaches, grapes and currants. The fertilizer applications are being continued as before and are as follows:

Plot 1. No fertilizer
2. Nitrate of soda
3. Acid phosphate
4. No fertilizer
5. Muriate of potash
6. Nitrate of soda and acid phosphate
7. Nitrate of soda and muriate of potash
8. No fertilizer
9. Acid phosphate and muriate of potash
10. Nitrate of soda, acid phosphate and muriate of potash
11. Land plaster
12. No fertilizer
13. Nitrate of soda, acid phosphate, muriate of potash and dried blood.

The west halves of all plots have been limed from time to time, most recently in 1914. While this field presents very abnormal conditions, it was felt that it should give some valuable information of the fertilizer needs of fruit plants.

No responses to fertilizer treatment were seen before mid-July, but from then on there were gradually increasing differences between the trees on the different plots. It was evident that nitrogen and potash were both needed for the peach trees. There was nothing to indicate that phosphorus was needed by the peach trees even on those plots that had had no addition of phosphorus for thirty years. Indeed the peach trees on plot 3, receiving only acid phosphate, were inferior to those on the check plots and especially so on the limed portion.

Pomology Project 18. "Comparison of cultivation and heavy mulching for apples and pears."

Professor Shaw.

Two one-half acre blocks, one of Wealthy apple and the other of McIntosh apple interplanted with Bosc pear, were divided into two parts, and one-half of each carried on the cultivation and cover crop system and the other half heavily mulched with swale hay from the neighboring lowlands. Fertilizers will be used as they seem necessary. This project is related to Projects 5, 6, 7 and 8 discussed above.

Crop and Crop Management Studies.

The studies carried on under this head are devoted mainly to the general problem of improving on existing conditions. Attempt is made to determine the adaptability of new crops as they may be introduced into Massachusetts, to find improved varieties, and to enable farmers to make selection among varieties offered; and to breed better varieties. There is also included in this group of studies work designed to develop better methods of handling our present crops.

The work under way in these several lines is as described in the following:

Plant Introduction.

Cranberry Station Project 5. "Blueberry investigations."

Professor Franklin.

This project was commenced in 1915, and is co-operative with the Bureau of Plant Industry of the United States Department of Agriculture. Preliminary tests with fertilizers were started during the year, and extensive budding continued. Planting and budding have both gone about as far as present facilities permit. More land and a propagating house are needed for this work.

Pomology Project 17. "A study of the cultivation of the high bush cranberry."

Professor Shaw.

Two hundred plants of Viburnum were received in the spring of 1921 from the United States Department of Agriculture and set out. A few of these plants bore a few clusters of berries. As soon as a crop is produced, affording a basis for selection, it is expected to carry out some work in propagation of desirable types.

Strain and Variety Tests.

Agriculture Project 5. "Test of meadow fescue *versus* timothy under varying drainage conditions."

Assistant Professor Gaskill and Mr. Coffin.

The 1922 hay crop did not show any great superiority of one grass as compared to the other. Timothy gave the larger crop on the wetter portions of the field, the fescue outyielded the timothy on the drier portions.

Agronomy Project 1. "Investigation of the value of Hubam or annual sweet clover as compared to the biennial sweet clovers."

Professor Michels.

The spring seeding of both the annual and the biennial sweet clovers was a failure, possibly due to the late date of sowing. Germination in the late summer season was poor. The yellow sweet clover had such a weak growth as to indicate no value. It will be discarded from future tests. The Hubam made a much heavier, fuller top growth than did the biennial clover, but on the other hand the root growth of the latter was much the larger.

Market Garden Field Station Project 4. "Variety and strain test of tomatoes."
Professor Tompson.

Uniformity in growth conditions for the plants worked with in this test was prevented by an exceedingly high wind storm a few days after the plants were set. For this reason records of growth and behavior were not taken.

Pomology Project 2. "A study of tree characters of fruit varieties."
Professor Shaw and Mr. French.

Bulletin 208, "Leaf Characters of Apple Varieties" has been prepared and published during the year. The nursery certification work which has grown out of this project is developing and about 10,000 trees were examined this year. It is hoped to undertake further work with bud, bark, wood and growth habits this winter.

Pomology Project 13. "Study of varieties of tree fruits."
Professor Shaw and Assistant Professor Gould.

Records of date and amount of bloom of practically all varieties of tree fruits on the college grounds, and individual tree yields have been secured for the season of 1922.

Breeding.

Market Garden Field Station Project 6. "Improvement of Martha Washington asparagus."
Professor Tompson.

The second-year records of the 1,062 asparagus plants being studied in this investigation indicate that the comparative behavior of individual plants is fairly constant. The records also indicate a difference both in yield and in quality of product, due to the sex of the plant, which is the exact opposite of what was formerly thought to be the case. Thus far no practicable method of vegetative propagation of high yielding plants has been found.

Pomology Project 3. "The genetic composition of peaches."
Professor Shaw.

1922 failed to give a crop in this orchard. The trees are now old enough to warrant actual crossing work, which will be attempted in the spring of 1923 in case the fruit buds survive the winter.

Orchard Management.

Pomology Project 4. "Experiments in pruning apples."
Professor Shaw.

The average weight of 300 trees removed in the spring of 1922 indicates that the general law that pruning decreases tree growth in direct relationship to its severity holds as far as the trees under experiment were concerned.

Pomology Project 9. "Testing methods of pruning" and Pomology Project 10. "Testing of pruning methods on Northern Spy and other varieties."
Professor Shaw.

The time of summer pruning in Project 9 was changed from August to May, the purpose being to prevent undesired growth rather than remove it after it was made.

The Spy trees in Project 10 bore a small crop of apples. There seemed to be little if any benefit from either of the two pruning methods used over the unpruned trees, either in size of crop or quality of fruit.

Crop Protection.

As agriculture becomes more intensive, its susceptibility to disease and insect attack usually becomes greater. This is particularly the case in Massachusetts, which, because of its situation on the channels of world commerce, is open to injury from accidental importation of foreign insects and diseases. It is probable that as time goes on there will be increasing necessity of studies relative to crop protection. This is due in part to the danger of introduction of new diseases, and secondly to the fact that increasing value of farm crops brings about increased financial loss when these are damaged by fungous diseases or insect enemies.

Insect Enemies of Vegetation.

Entomology Project 2. "Economic importance of digger wasps."
Professor Fernald.

Because of the pressure of other duties, no work was done on this project, during the 1922 season.

Entomology Project 3. "Control of the onion maggot."
Assistant Professor Bourne.

Weather conditions the past year were such as to make the stand of onions on the experimental fields so variable as to make the records valueless for experimental purposes.

Entomology Project 4. "Control of squash vine borer."
Mr. Worthley.

Tentative control measures which were developed during 1921 were tried on a commercial scale at Amherst and at Lexington. The cost of such treatments was determined. The seasonal history of the borer in Amherst was compared with its history at Lexington so that control measures may be so timed as to be applicable to the Boston Market Garden District as well as to the Connecticut Valley.

Entomology Project 5. "Control of the squash bug."
Mr. Worthley.

The main effort has been to find a material toxic to the adult bugs but not toxic to the plants. To date these efforts have been only partially successful. The life history of the Tachinid parasite of the squash bug, *Trichopoda pennipes*, has been worked out, and its relation to its host determined. Papers on the life history of the squash bug in Massachusetts and the control measures tried, and on the parasite, are being prepared for publication.

Entomology Project 7. "Studies of insect outbreaks in various localities."
Professor Fernald.

This is a continuing project, the subject being entirely dependent upon the insects which may appear. In 1922 the conditions as related to the corn ear-worm and seed corn maggot, which were the insects studied in 1921, were continued and concluded; and the appearance of the birch leaf skeletonizer and the apple and thorn skeletonizer led to their study as well.

Entomology Project 8. "Pest limits in Massachusetts."
Professor Fernald.

Data on this subject are gathered each year as they appear and can be obtained. Some additions were made in 1922.

Entomology Project 9. "Number of generations of codling moth in Massachusetts as related to advisability of spraying for the second generation."

Assistant Professor BOURNE.

The accumulation of data on the codling moth has now reached a point where, with good fortune, final results may be anticipated in the course of two or three seasons. Co-operative work with a fruit grower in the Nashoba fruit district has added value to the work, giving a broader knowledge of conditions in Massachusetts.

Entomology Project 10. "Hatching dates for scale insects."

Assistant Professor BOURNE.

The necessary observations for 1922 have been made and recorded. To be of value, these records should be made over a long period of years, to insure inclusion of years of abnormal conditions as well as normal ones. The behavior of the insects under normal conditions has been determined with considerable accuracy. Their reaction to abnormal seasonal conditions, such as very open, mild winters, or unusually cold winters, makes further study advisable. Records on other points in the life cycle of these scales have been secured, with especial reference to the possibilities of their furnishing more accurate data on this problem.

Cranberry Station Project 1. "Injurious and beneficial insects affecting the cranberry."

Professor FRANKLIN.

The more important results of the year's operations were the following:

A very effective control for the root grub (*Amphicoma vulpina* Hentz.), by soaking the soil with a solution of sodium cyanide, was developed.

A satisfactory control for the yellow-head fireworm (*Peronea minuta* Rob.) by killing the moths with a spray of nicotine sulfate and soap in the dormant season was perfected. Experiments also showed that this pest can be controlled with a lead arsenate spray used at the time and strength to be most effective against the gypsy moth.

It was found that the red-striped fireworm (*Gelechia trialbamaculella* Cham.) can be controlled well with a nicotine sulfate and soap spray applied while the worms are in the tips of the vines.

Dusting with nico-dust to control the black-head fireworm (*Rhopobota naevana* Hübner) proved effective but not practicable because of the expense.

Extensive spraying experiments to discover a cheaper control for black-head fireworm were conducted, with mostly negative results.

A fungus, apparently a new species of *Entomopthora*, was found causing such an epidemic among the black-head fireworms on one bog that it seemed an almost perfect control. The fungus was successfully cultured on fish. It presents interesting possibilities for further control work.

Important observations were made on the phenomenon of the occasional marked disappearance of black-head fireworm eggs while covered by the winter flood.

Many new facts were learned concerning the life histories of the following minor cranberry pests:

1. *Cacoccia parallela* Rob.
2. *Sparganothis sulfureana* Clemens.
3. *Noctua c-nigrum* L.

The work of the fruit worm (*Mineola vaccinii* Riley) was observed to be light in spite of the fact that the egg parasite (*Trichogramma minuta*) was much less prevalent than normally. The egg hatching of this pest was earlier than usual, so the worms did little harm among stored berries. Further attempts to discover a practicable means of control by wetting the cocoons with chemicals during the dormant season resulted negatively.

PLANT DISEASE CONTROL.

Botany Project 3. "Tobacco investigations and a study of so-called tobacco sick soils."

Professor OSMUN and Professor ANDERSON.

This project embraces a study of soil reaction as a means of controlling root-rots of tobacco; also a study of the effects of soil reaction on the growth and development of tobacco. During the last season, further study was made of the influence of cover-cropping and liming on the development and effect of black root-rot, caused by *Thielavia basicola*, and considerable data were obtained. An important feature of this year's field work was the successful infestation by artificial means of experimental field plots with Thielavia. With permanent plots known to be infested with this fungus and others free from it, valuable results should be obtained in the next few years.

Botany Project 4. "Investigations of the methods of controlling lettuce drop."
Professor OSMUN and Assistant Professor KROUT.

The work on this project has been completed. The investigation involved preliminary study of the reaction of the drop fungus, *Sclerotinia libertiana*, to various factors and extensive testing of these factors in their relation to the control of the disease in the greenhouse. The net practical result is the definite determination that the disease may be controlled with relatively little expense by treating infested soil with formaldehyde. A 1–100 solution applied to the surface of the soil at the rate of one gallon to the square foot was found efficacious. It was found also that treatment must begin in the seed-bed to prevent infection of young plants before transplanting to the main house. Details of practice were worked out in some of the commercial houses of the State.

Botany Project 5. "Experimental spraying for the control of cucumber mildew under glass."
Assistant Professor KROUT.

Bordeaux gave slightly better results this past season than did a copper-lime dust. Full control, however, is not yet obtained.

Botany Project 6. "Investigation of onion diseases."
Professor OSMUN and Professor ANDERSON.

As stated in the last report, the work on this project has been focused on a study of onion smut and its control. Technical Bulletin No. 4, "Development and Pathogenesis of the Onion Smut Fungus", distributed early in the present year, is a report of some of the more technical features of this work. Field tests of formaldehyde applied at different concentrations and rates were continued this year. In co-operation with the Department of Rural Engineering, the apparatus for applying formaldehyde has been perfected to the extent that errors due to uneven distribution of the fungicide have been eliminated. The development of this equipment renders advisable the continuance of field tests for at least one more season. The use of the new equipment by practical growers gave some very interesting and significant results.

Botany Project 9. "Investigation of carrot blight."
Assistant Professor KROUT.

The work on this project was conducted along the same lines as reported last year. Considerable attention was given to study of the etiology of the disease and it has been definitely established that the pathogene is a Macrosporium. The incubation period has been determined and physiological studies of the organism are in progress. In the field, considerable benefit was shown from spraying with Bordeaux mixture, but definite conclusions can be drawn only from the results of several years' work.

Botany Project 10. "Apple disease control investigations."
Assistant Professor KROUT.

The work on this project has been confined almost wholly to an investigation of the control of scab. Very satisfactory progress has been made and much of importance to the practical orchardist has resulted. It has been definitely established that the McIntosh apple, which is very susceptible to attack by scab, can be protected against this disease by spraying with fungicides. Results from dusting also have been excellent, but further tests are necessary. The best results have been obtained by the use of a 3–10–50 home-made Bordeaux mixture for the pre-pink and pink applications, followed by liquid lime-sulphur, 1–50, for the summer sprays. The most satisfactory results from dusting were obtained with finely ground sulfur. Copper-lime dust proved effective in controlling scab, but serious russeting of the fruit by this material definitely eliminates it as a possible apple fungicide, at least for summer application.

Meteorological records were kept and important observations on the relation of meteorological conditions to sporulation, spore ejection and infection by the scab fungus were made. These data, taken over a series of years, will be invaluable in establishing a definite and permanent spraying or dusting schedule for the State.

Early in the year the leader of this project, Mr. W. S. Krout, established his residence in the eastern part of the State. This has enabled him to keep in more intimate touch with the field work and has made possible considerable expansion over last year's plan.

Botany Project 14. "Investigation of control of tobacco wildfire."
Professor Anderson.

The disease known as Wildfire has created a grave situation in the tobacco growing industry of the Connecticut Valley. The seriousness of the outbreak the last season, and consequent imperative need of solving the problem of control, made a constant demand on the time of the leader of this project, as well as of others of the department. The importance of thoroughly familiarizing himself with the disease, both in the seed-bed and field, kept the investigator out of the laboratory and on the tobacco farms a considerable portion of the time. In this way much information was gathered which will prove useful in the furtherance of the investigation.

Botany Project 16. "Relation of soil character to occurrence of onion smut."
Professor Anderson.

No progress on this project was made during the past year, on account of lack of time.

Cranberry Station Project 2. "Cranberry Disease Work."
Professor Franklin.

This project was conducted, as heretofore, co-operatively with the Bureau of Plant Industry of the United States Department of Agriculture. Extensive culture work was done to discover the variation in the cranberry fungus flora among different classes of bogs, especially with reference to differences in their flooding.

Studies were pursued to determine more definitely the relationship of the weather to deterioration of cranberry keeping quality from the activity of putrefactive fungi.

Extensive tests were conducted to determine the effect on cranberry keeping of the Wisconsin method of picking known as "water-raking." This was found to be very harmful.

Extensive storage tests were also made to determine the effect on cranberry keeping of picking during the heat of the day as compared with picking late in the afternoon. The harmful effect of the former was clearly demonstrated.

Spray Materials — their Nature and Use.

Botany Project 17. "Potato spraying-dusting."
Professor Osmun and Professor Anderson.

This project has for its main object the making of comparative tests of home-made Bordeaux mixture and copper-lime dusts for combating late-blight and other leaf diseases of the potato.

The conclusions from the first year's work are:

1. Dusting with hand dusters has not been as efficient as spraying with a power sprayer.
2. Dusting by hand costs more than power spraying.
3. The percentage of rotten potatoes was higher in the treated plots than on the check plots. This was probably due to the fact that the vines on the check plots dried earlier and the moisture conditions were then less favorable to development of the disease than where the soil remained covered several weeks longer with a dense mat of vines.
4. Both spraying and dusting resulted in considerable increase in yields over the checks. Spraying gave the greater increase.

Chemistry Project 5. "Chemistry of arsenical insecticides."
Professor HOLLAND and Mr. DUNBAR.

This project is no longer confined to arsenical insecticides, but has practically become a study of the chemistry of insecticides and fungicides. The work is in large measure co-operative with other departments of the State and Station, and is largely confined to analytical work.

It has furnished needed information relative to various types of commercial sulfur compounds, although as yet scientific entomological and pathological data are lacking for the interpretation of analytical results in terms of toxicity, or preferably of efficiency. This in a measure is also true of waste tobacco.

Chemistry Project 13. "A new method for the analysis of dry lime-sulfur mixtures."
Assistant Professor JONES.

Work on this project has been completed, and report submitted for publication.

Chemistry Project 20. "A study of the fundamental factors affecting the suspension, adhesiveness, toxicity and general efficiency of copper fungicides."
Professor HOLLAND and Mr. DUNBAR.

The work outlined is very extensive, including chemical, physical and pathological studies of a considerable variety and large number of compounds, requiring more or less co-operation by the Departments of Botany and Physics, and final verifications by field experiments. A portion of the literature has been reviewed, preliminary work on production of some of the compounds undertaken, stability and certain physical properties have been noted, and hundreds of suspension tests have been conducted to determine the effect of different amounts of lime under varying conditions and the influence of protective colloids and deflocculating agents.

Entomology Project 1. "Studies of causes of burning of foliage by arsenicals."
Professor FERNALD and Assistant Professor BOURNE.

This work has been completed, and Bulletins Nos. 207 and 210 of this Station give the results with lead arsenate, lime arsenate and some other arsenicals. A third bulletin, on Paris green, is in preparation.

Entomology Project 12. "Determination of the best strength of lime-sulfur."
Assistant Professor BOURNE.

Tests of various dry sulfids have been made under differing conditions, in comparison with different strengths of the liquid lime-sulfur. The tests have not sufficiently covered the ground as yet to make a report of results possible.

Entomology Project 13. "Study of the possible injurious effects of Scalecide on trees."
Assistant Professor BOURNE.

Tests of this material must be continued for several years before results can be reported.

Entomology Project 14. "Does spraying orchards kill bees?"
Assistant Professor BOURNE.

The investigations thus far have been quite suggestive, particularly indoor ones, but the inclement weather following the "calyx spray" out of doors last spring makes further studies necessary.

Entomology Project 15. "Determination of efficiency of nicotine sulfate dusts."
Assistant Professor BOURNE.

The nicotine sulfate dusts proved very effective in nearly all tests. The high prices of these dusts, however, often prohibit their use. Dusts of ground tobacco, reinforced with nicotine sulfate did not give as satisfactory results, chiefly because of their inferior physical qualities. Comparative tests of superfinely ground tobacco dusts have been planned for another season.

Entomology Project 16. "Investigation of materials which promise value in insect control."

Assistant Professor BOURNE.

This is a continuing project covering materials as they may appear. This season two materials were tried out — Derris and Flyosan. The tests with Derris in its various forms were quite satisfactory as far as they went, and further tests of this material will be made the coming year. When these tests have been completed a final report on Derris can be made. Flyosan in some of the tests also gave good results, but more studies of it are necessary before full statements would be advisable.

Pomology Project 11. "To test new spray materials as they become commercially important."

Professor SEARS and Assistant Professor GOULD.

The following materials were tried out this year in comparison with standard liquid lime-sulfur and arsenate of lead: Bordeaux mixture 3–10–50, Nurexo Bordeaux Lead, Nurexo Spraydried, Celesto, Sulfurex, Sulfocide, Sulco V-B, Dry Lime Sulfur, Nurexoform Lead, Calcium Arsenate and Cal Arsenate.

While some of these materials gave good results, none of them gave promise of sufficient merit to replace liquid lime-sulfur and lead arsenate.

Animal Nutrition.

The use of purchased concentrates, mixed or unmixed, is the salient characteristic of Massachusetts animal industry. The cost to the industry, and finally, of course, to the consumer of its products, is immense; possible waste, in case the materials are unwisely used, or bought on the basis of ignorance instead of knowledge, enormous. The work of the Station in this direction has, therefore, two objectives: first, to develop a basis for the productive feeding of these articles; and secondly, to measure the characteristics of various feedstuffs, so that dairymen may have a sound basis of purchase.

DIGESTIBILITY OF FEEDING STUFFS.

Chemistry Project 2. "Digestion experiments."

Professor LINDSEY and Assistant Professor ARCHIBALD.

In addition to digestion experiments made in connection with projects 12 and 19, one experiment was made with cocoa dust, with results incorporated in manuscript already prepared on "Digestibility of Cattle Feeds."

Chemistry Project 9. "Determining the digestibility and metabolizable energy in feeds for horses."

Professor LINDSEY and Assistant Professor ARCHIBALD.

Final report is now being prepared for publication.

Chemistry Project 12. "Attempting to improve the nutritive value of grain hulls."

Assistant Professor ARCHIBALD and Professor LINDSEY.

Considerable progress has been made on this project. In addition to the treatment and determinations of digestibility of oat and rice hulls already reported, the following materials have been treated and the influence of treatment on digestibility determined: — namely, barley hulls, cottonseed hulls, and flax shives. In addition to the regular analysis, determinations of starch, galactan, pentosans, and lignin have been made on the natural and treated materials, and determinations of the above substances are now being made in the feces.

It can be said that the digestibility of the barley hulls has been greatly improved, but the treatment has been substantially without effect upon the cottonseed hulls and the flax shives. The method of treatment — namely, with dilute sodium hydrate — would probably not prove economical on a large scale.

Animal Feeding.

Chemistry Project 10. "Experiments in feeding pigs."
Professor Lindsey and Assistant Professor Archibald.

This project consisted in the taking of records on feeding different amounts of semi-solid and dried buttermilk. Results indicate that these materials are uneconomical when used for pork production. Work under this project is completed, but results have not yet been submitted for publication.

Chemistry Project 16. "Vitamines as aids in the production of growth in pigs."
Professor Lindsey.

As with the above, work has been completed, temporarily at least.

Chemistry Project 17. "Attempting to secure a substitute for milk in the growing of young calves."
Professor Lindsey and Assistant Professor Archibald.

Four different materials or combinations of materials were used as milk substitutes, with a total of twenty-three calves used in the investigation, but with four discarded as unsatisfactory. In these different mixtures limited amounts of soluble blood flour, dried skim milk, oat flakes, corn meal, wheat middlings, coconut meal, peanut meal, linseed meal, starch, glucose, milk sugar, calcium chloride and salt were used. Fair results were secured.

Chemistry Project 18. "To determine the mineral constituents of forage crops."
Professor Lindsey and Assistant Professor Archibald.

This study has been fruitful in two directions: first, the collection of about sixty samples of coarse fodders, principally hay and corn silage, from different parts of the State; and secondly, determination of the mineral constituents in the ordinary concentrates which are used in the State. It is expected that this work will be completed during the coming winter.

Chemistry Project 19. "The value of inorganic calcium phosphate in the promotion of growth and milk production.
Professor Lindsey and Assistant Professor Archibald.

Up to date no effect favorable or otherwise of feeding inorganic calcium phosphate to cows, young stock and sheep has been noted. Despite this failure, however, these inorganic salts are widely used in the State as constituents of animal feeds. Their value is yet to be proven.

Miscellaneous.

Chemistry Project 3. "Summer forage crops."
Professor Lindsey.

Very little work was done on this project. There are no results worthy of extended comment.

Chemistry Project 4. "Record of the station herd."
Professor Lindsey.

As in previous years complete records on the food cost of milk produced by the station herd have been kept.

Studies of Heredity in Poultry.

The Massachusetts poultry industry is essentially intensive. It operates fairly large flocks, but on relatively small areas. Most of the food consumed is purchased, imported largely from the grain sections of the West. In order that the Massachusetts industry may compete with that of other sections of the country, it is necessary that the stock be of the highest possible grade. This fact gives a peculiarly important economic significance to the work grouped in the following:

Poultry Husbandry Project 1. "Broodiness in poultry."

Professor Hays.

The broody trait in poultry is being studied from the following angles:

1. Possibility of establishing a strain of broody-free Rhode Island Reds by systematic matings in pedigreed lines. An approach to this goal has been made in some families.
2. Specific intensification of broodiness by the pedigree system of matings.
3. The behavior of the factor or factors for broodiness in crosses.
4. The physical relationship of different organs to broodiness.

Poultry Husbandry Project 2. "To determine the mode of inheritance of various characters in poultry, and to study factors governing form and function."

Professor Hays.

The basic idea for which this project has been carried is the analysis of the mode of inheritance of factors for egg production. The results seem to indicate that at least four or five pairs of factors are concerned. Progress of a very definite character has been made by handling these factors as units in breeding.

Human Food.

The increasing cost of food products has brought about the necessity of more attention being given to the conservation of food. Conservation essentially requires control of those forces and agencies which cause decay and loss; and as a first step a study of the conditions under which these agencies develop. The very small amount of time given to this subject at this Station is not a measure of the importance of the work. In fact the well-being of the great food-consuming population of the State would be furthered were this work to be greatly increased.

Microbiology Project 1. "Microbiological investigations in milk."

Mr. Avery and Mr. Neill.

The following articles have been prepared during the year:

"A Biological Study of the Hemolytic Streptococci from Dairy and Human Sources: The Differential Reaction of Methylene Blue." Roy C. Avery.

"A Review of the Literature of Lactic Acid Fermentation." James M. Neill.

"A Study of the Characters of the Streptococci of Dairy Lactic Acid Fermentations, with Special Reference to the Present Status of the So-called *Streptococcus Lacticus* Group." James M. Neill and Roy C. Avery.

"A Comparative Study of Different Types of Streptococci, with Special Reference to the Peptolytic Activity of the Lactic Group." James M. Neill.

At the present time, however, this work is at a standstill, owing to the fact that the men involved have left the institution or become burdened with other work.

Microbiology Project 3. "Canning investigations in the light of normal and resistant organisms in continuous, fractional and pressure methods of sterilization."

Professor Marshall and Mr. McCrimmon.

The first stage of this investigation is practically complete, although verification of the results is essential and an extension of certain determinations must be made. It is, however, being retarded owing to the resignation of Mr. McCrimmon.

Agricultural Economics.

The status of agriculture at any particular time and place is always the resultant of economic forces working in conjunction with those other forces which control the condition or productivity of the soil and the possibility of growing certain crops. Massachusetts has been slow to recognize this fundamental principle. It has failed in supporting economic research in agriculture in the way which the importance of the subject necessitates. The future of New England agriculture probably depends in large measure on economic conditions; and likewise the future of New England and Massachusetts as industrial units depends on the national development and maintenance of those economic conditions which will make possible continued production of food in suitable quantities. Much of the high cost of living, of which we hear so much complaint, is due not to deficiency in local production, but rather to avoidable waste in handling farm products.

Work has been done during the past year under the following projects:

Agricultural Economics Project 1. "Local balance of trade in farm products."
Assistant Professor Jefferson.

Study under this project has been continued. In addition to the material secured in Fitchburg, the gathering of similar information has been carried on in New Bedford so far as it is available for that city.

The local farm products of the vicinity of New Bedford are sold in that market without system of any sort. These products are chiefly vegetables, although a small quantity of fruit is also grown. Each grower sells his own produce in the way which appeals to him. Some few sell to the wholesalers, but the most common method is for the grower to stop at the first grocery store he reaches as he drives into the city, sell what he can, and go on to the next. Naturally, this brings each grower into competition with every other, reducing the price each one receives.

No local products are shipped out of New Bedford, and the local production falls far short of supplying the needs of the city, except in the case of turnips.

A large part of the milk supply is likewise local, but considerable quantities are received at certain periods from outside sources. Some of it comes from Maine and New Hampshire, but all is received through the Boston distributors.

There is very little local slaughtering done in New Bedford, although there are two local slaughterhouses, one in the city and the other across the river in Fairhaven.

Agricultural Economics Project 2. "Methods and cost of distribution of tobacco, onions and potatoes."
Professor Cance and Assistant Professor Jefferson.

An investigation of the supply and distribution of Connecticut Valley onions, already under way, was completed and the manuscript prepared for publication.

In addition to the preparation of this manuscript, material is at hand for a second, relating to the price of onions.

Agricultural Economics Project 7. "Boston food supply study."
Professor McFall.

This project was formally approved in July, 1922, on a co-operative basis between the Experiment Station and Extension Service. A large amount of time and energy has been expended in outlining the study and carrying on certain preliminary work. As organized, the leader of this project spends a part of each week in Boston, overseeing the work of a number of graduate students who are taking as their thesis problem certain of the subdivisions of the larger study. At the present time fourteen students are so engaged: three being from Boston University and eleven from the Massachusetts Institute of Technology. Certain other investigators are likewise co-operating, but in an informal way. The State Department of Agriculture is assisting in certain broader phases of the work. The committee on agriculture of the Boston Chamber of Commerce has co-operated in making a comparative study of the market reports of all public and private agencies reporting Boston markets. A certain amount of the financing of this work is done directly through a co-operative agreement with the Bureau of Agricultural Economics of the United States Department of Agriculture. Naturally, in its present formative stage, concrete results cannot yet be reported.

Rural Engineering.

The following project represents the first experimental work done by the Department of Rural Engineering since its formal organization as a Station department.

Rural Engineering Project 1. "Testing Low Lift Pumps."

Professor Gunness.

This project is co-operative between the Cranberry Station and the Department of Rural Engineering. It was made necessary by the fact that there has never been a comprehensive study made of the large capacity, low lift pumps as used so largely in the Massachusetts cranberry industry. The work occupied a large portion of the summer of 1922. Manuscript has been prepared and submitted for publication, the project in its present form being therefore complete.

Meteorological Studies.

The work of the Station in this direction consists in part of the taking of data at the home station as indicated by the following; and in part in the definite application of meteorological data to certain definite agricultural problems, notably that of cranberry bog management and secondly the relation of weather to insect development.

Meteorology Project.

The recording day by day of meteorological phenomena, and the publishing of monthly summaries for distribution to parties interested has been continued. The year just closed was the thirty-fourth over which this work has continued. When combined with the records taken by the late Professor Snell, the Station has an unbroken meteorological record of eighty-seven years. Work of this kind becomes more and more valuable as such records accumulate.

Entomology Project 11. "Study of area of the late frosts as shown by insect distribution."

Professor Fernald.

More light on this subject has been obtained during 1922. It will require many years for completion, but takes annually only the time necessary to record the data obtained.

Cranberry Station Project 3. "Weather observations with reference to frost prediction."

Professor Franklin.

As in past years, reports were telegraphed daily to the district forecaster at Boston. Further frost records were accumulated for study. Distribution of Station frost warnings was continued with the financial aid of the Cranberry Growers' Association.

METEOROLOGICAL OBSERVATIONS.

DEPARTMENT OF METEOROLOGY,

PROF. J. E. OSTRANDER, HEAD.

Annual Summary for 1922.

Pressure (in Inches).

Maximum reduced to freezing	30.36, Jan. 25, 10 A.M.
Minimum reduced to freezing	28.60, Oct. 11, 12 P.M.
Maximum reduced to freezing and sea-level	30.70, Jan. 25, 10 A.M.
Minimum reduced to freezing and sea-level	28.92, Oct. 11, 12 P.M.
Mean semi-daily reduced to freezing and sea-level	30.058
Annual range	1.78

Air Temperature (in Degrees Fahrenheit).[1]

Highest	94.0, July 12, 4.00 P.M.
Lowest	—13.5, Feb. 18, 7.30 A.M.
Mean hourly	47.2
Mean of means of max. and min.	47.8
Mean sensible (wet bulb)	43.0
Annual range	107.5
Highest mean daily	76.7, Aug. 16
Lowest mean daily	—0.8, Feb. 17
Mean maximum	58.3
Mean minimum	37.3
Mean daily range	21.0
Greatest daily range	43.5, Apr. 10
Least daily range	3.5, Nov. 7

Humidity.

Mean dew point	39.2
Mean force of vapor	.380
Mean relative humidity	78.7

Wind.

Prevailing direction	West

Summary.

South Southwest	19 per cent
Northwest	12 " "
North	10 " "
West Northwest	10 " "
Southwest	10 " "
Other directions	39 " "
Total movement	49,970 m.
Greatest daily movement	467 m., Dec. 6
Least daily movement	12 m., Jan. 17
Mean daily movement	137 m.
Mean hourly velocity	5.7 m.

Maximum pressure per square foot, 30.0 lbs., =78 m. per hour, Jan. 22, 12 M., W.

Maximum velocity for 5 minutes, 42 m. per hour, Jan. 22, 12 M., W.; June 12, 2 P.M., W.N.W.

Precipitation (in Inches).

Total precipitation, rain or melted snow	45.94
Snow total in inches	58¾
Number of days on which .01 or more rain or melted snow fell	120

Weather.

Mean cloudiness observed	45 per cent
Total cloudiness recorded by Sun Thermometer	1,932 hrs. =43 per cent
Number of clear days	117
Number of fair days	127
Number of cloudy days	121

Bright Sunshine.

Number of hours recorded, 2,522 hrs. =57 per cent.

Dates of Frosts.

Last	May 12
First	Sept. 19

Dates of Snow.

Last	April 23
First	Nov. 24
Total days of sleighing	74

Gales of 50 or More Miles per Hour.

Jan. 22, 78 m., W.; Mar. 7, 63 m., S.; April 20, 53 m., W.N.W.; June 12, 56 m., W.N.W.; July 8, 57 m., S.S.W.; Dec. 29, 57 m., N.

[1] Temperature in ground shelter.

REPORT OF THE TREASURER.

FRED C. KENNEY.

United States Appropriations. 1921–22.

		Hatch Fund.	Adams Funds.
Dr.			
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1922 under acts of Congress approved March 2, 1887 and March 16, 1906		$15,000 00	$15,000 00
Cr.			
Adams:			
By salaries	$14,947 50		
Labor	52 50		
	$15,000 00		15,000 00
Hatch:			
By salaries	$14,632 50		
Labor	367 50		
	$15,000 00	15,000 00	

State Appropriations, 1921–22.

Cash balance brought forward from last fiscal year	–
Cash received from State Treasurer	$99,152 86
fees	18,648 95
sales	9,690 25
miscellaneous	378 20
	$127,870 26

Cash paid for salaries	$60,164 33
labor	17,459 50
publications	2,017 25
postage and stationery	1,767 69
freight and express	429 75
heat, light, water and power	745 56
chemicals and laboratory supplies	3,049 88
seeds, plants and sundry supplies	2,290 32
fertilizer	689 11
feeding stuffs	1,386 20
library	635 79
tools, machinery and appliances	1,167 54
furniture and fixtures	987 31
scientific apparatus and specimens	292 09
livestock	230 82
traveling expenses	4,819 60
contingent expenses	10 00
buildings and land	1,010 12
Remitted to State Treasurer	28,717 40
Total	$127,870 26

BULLETIN No. 207.

DEPARTMENT OF ENTOMOLOGY.

INJURY TO FOLIAGE BY ARSENICAL SPRAYS.

I. THE LEAD ARSENATES.

BY H. T. FERNALD AND A. I. BOURNE.

It has long been known that arsenical poisons sprayed upon foliage will at times produce injury, or a "burning" of the leaves. For this, four explanations have been offered, viz., (1) that the arsenic (either As_2O_3 or As_2O_5, as the case might be) was present in the material, uncombined with any base; (2) that it was so loosely combined with the base as to become liberated from it during the addition of water in preparing it for application to the foliage; (3) that this liberation took place more or less gradually on the leaves after the spray had been applied, as a result of influences acting upon the material through the air; and (4) that injury was due to the presence of injurious impurities in the material.

Faulty methods of manufacture might easily result in producing a substance containing some arsenic, either free or so poorly combined that upon the addition of water the combination would break up, at least to some extent. The use of poor materials from which to make the lead arsenate might very possibly result in the presence of injurious substances. The liberation of arsenic upon the tree by atmospheric influences, however, comes distinctly in a different class; and the statement sometimes made, that spraying a tree with water under the right conditions may result in burning, if true, also suggests that atmospheric conditions must not be overlooked. The entire problem, therefore, of ascertaining what factors are really responsible for foliage injury following arsenical spraying has been investigated during a period of about ten years.

This bulletin reports the results of this work with the various lead arsenates. Similar reports upon arsenates of lime and Paris green are nearly ready for publication, together with notes on a number of other arsenicals which have been tested more or less.

The planning of the project, the plotting and analysis of the results, and the preparation of the material for publication are the work of the senior author; the preparation and application of the sprays, and the observations to determine their effects, were carried out by the junior author; the chemical analyses and all the chemical work involved were done by Dr. E. B. Holland and his assistants of the Department of Plant and Animal Chemistry of the Experiment Station, and to him and to those who worked with him the authors desire to express their appreciation of the efforts made to establish this work on a firm chemical basis.

Materials.

To eliminate the possibility that injury was caused by impurities in the spray materials, pure arsenates were first sought. A definite knowledge of the action of these appeared to be desirable, as, if injury resulted from their use, it seemed probable that the factors causing it would be indicated, uncomplicated by the presence of injurious impurities, uncombined arsenic or too loosely combined arsenic. In fact, such knowledge would provide a basis or standard with which to compare results obtained from the use of commercial materials. Accordingly, the attempt was made to obtain pure acid lead arsenate and pure neutral lead arsenate.

To get these seemed at first to be almost impossible. A number of manufacturers were willing to supply them, but the samples received proved on analysis to be far from pure, and nearly two years passed before materials were found so nearly pure that it was believed they would be satisfactory.[1]

Pure Acid Lead Arsenate Paste. — The material used in these experiments analyzed as follows: —

	Per Cent.
Water, H_2O	46.99
Water in combination and occlusion	1.33
Lead oxide, PbO	34.58
Arsenic pentoxide, As_2O_5	17.11
Chlorine, Cl	.04
Insoluble matter	.01
	100.06

The probable original composition of the paste, reconstructed from this analysis, was substantially as follows: —

	Per Cent.
Water, H_2O	46.99
Water occluded	.09
Acid lead arsenate, $PbHAsO_4$	47.87
Neutral lead arsenate, $Pb_3(AsO_4)_2$	4.93
Lead chloride, $PbCl_2$	.16
Insoluble matter	.01
	100.05

[1] See Holland and Reed: The Chemistry of Arsenical Insecticides, Twenty-fourth Annual Report, Mass. Agr. Exp. Station, Part I, pp. 180–182, 1912, for a fuller discussion.

The impurities present here — the lead chloride and insoluble matter — occur in such infinitesimal amounts and are of such a nature that they certainly could not cause any injury on foliage.

As the purpose of using this material was to test acid lead arsenate, the presence of nearly 5 per cent of the neutral salt was unfortunate; but, as will be shown in studying the results following the use of the neutral salt, its presence here would, if anything, tend to increase the safety of the spray rather than reduce it. The substance, then, was rather more than half arsenates of lead and rather less than half water.

This material, mixed with water at the rate of 1 part of the dry matter of the paste to 1,000 of water and kept twenty-four hours, gave .03 per cent of arsenic pentoxide (As_2O_5) as entering into solution during that time. As the Federal law permits .75 per cent of solubility under such conditions, it is evident that the sample was of excellent quality from this standpoint.

The rate at which lead arsenate settles when mixed with water is also an important factor, those brands which settle most slowly being distributed most evenly over the tree in spraying. This sample had completely settled eighty-one minutes after a thorough mixing, which is excellent for paste lead arsenates.

Commercial Lead Arsenate Paste. — This material, purchased from a dealer, was of a brand commonly used. Analyzed, it gave: —

	Per Cent.
Water, H_2O	46.32
Water in combination and occlusion	1.26
Lead oxide, PbO	35.44
Arsenic pentoxide, As_2O_5	16.29
Ferric and aluminum oxides	.19
Chlorine, Cl	.31
Nitric acid, HNO_3	trace
Insoluble matter	.04
	99.85

The probable original composition of this paste was substantially as follows: —

	Per Cent.
Water, H_2O	46.32
Water in occlusion	.19
Acid lead arsenate, $PbHAsO_4$	37.96
Neutral lead arsenate, $Pb_3(AsO_4)_2$	13.50
Iron and aluminum as ferric arsenate	.54
Lead chloride, $PbCl_2$	1.22
Nitric acid, HNO_3	trace
Insoluble matter	.04
	99.77

In this material less than 2 per cent could be termed impurities, and these were of such a nature as to make it practically certain they could not cause any injurious effect on foliage. Rather more than half of the whole consisted of arsenates of lead, but the neutral salt formed a much greater part of the total than was the case with the pure material. About the same amount of water was present as in the pure substance. Or, the total amount of arsenate in the two did not differ greatly, but there was more than three times as much of the neutral arsenate in the commercial salt as in the pure one, the acid arsenate being correspondingly decreased. Any marked difference in the results following spraying by these materials, then, might possibly be explained by this difference in composition. In fact, the results did not differ greatly.

This paste, mixed with water as described for the pure paste, gave .09 per cent of arsenic pentoxide as entering solution in twenty-four hours. This, though more than with the pure paste, is also far below the amount permitted by the Federal law. Complete settling after mixing with water required only thirty-four minutes, showing that this commercial material was rather poor in this regard as compared with the pure paste.

Commercial Acid Lead Arsenate Powder. — The appearance on the market during the progress of these experiments of lead arsenate in powder form led to the addition of this material to the list of substances to be investigated. Samples from a brand on sale were obtained, analyzed and tested like the others. The analysis gave: —

	Per Cent.
Water, H_2O	.45
Water in combination and occluded	3.20
Lead oxide, PbO	63.25
Arsenic pentoxide, As_2O_5	32.22
Ferric and aluminum oxides	.40
Insoluble matter	.38
	99.90

From this the original composition of the powder was probably substantially as follows: —

	Per Cent.
Water, H_2O	.45
Water in combination and occluded	.68
Acid lead arsenate, $PbHAsO_4$	89.93
Neutral lead arsenate, $Pb_3(AsO_4)_2$	7.28
Iron and aluminum as ferric arsenate	1.16
Insoluble matter	.38
	99.88

This material as used for spraying, therefore, contained a little more than 1 per cent of water, about 90 per cent of acid lead arsenate, rather more than 7 per cent of neutral lead arsenate, and about 1½ per cent of impurities, none of them of a nature or present in sufficient amount to be liable to cause any injury.

The amount of arsenic pentoxide which had entered into solution after twenty-four hours of treatment was .16 per cent, which, though more than with either of the other materials already considered, was still far below that permitted by the Federal law. The time required for the powder to settle was 255+ minutes, which places this sample far ahead of either of the pastes in this regard.

Pure Neutral Lead Arsenate Paste. — This material has been highly recommended as being safer on foliage than the acid lead arsenates, and an investigation of it was therefore also made. To obtain it in a pure or nearly pure form was very difficult, however,[1] and the best sample obtainable analyzed as follows: —

	Per Cent.
Water, H_2O	70.97
Water in combination (calculated)	.08
Lead oxide, PbO	21.10
Arsenic pentoxide, As_2O_5	7.33
Acetic anhydride, $C_4H_6O_3$	.10
Sodium oxide (calculated to combine with last)	.06
Carbonic acid, CO_2	.15
Insoluble matter	.01
	99.80

The original composition of this sample was therefore substantially as follows: —

	Per Cent.
Water, H_2O	70.97
Water occluded	–
Acid lead arsenate, $PbHAsO_4$	3.14
Neutral lead arsenate, $Pb_3(AsO_4)_2$	24.61
Lead carbonate, $PbCO_3$	.91
Sodium acetate, $NaC_2H_3O_2$	.16
Insoluble matter	.01
	99.80

This sample contained a very large amount (71 per cent) of water, was nearly one-quarter neutral lead arsenate, and contained a little over 3 per cent of acid lead arsenate and rather more than 1 per cent of impurities of such a nature as to indicate that it had not been sufficiently washed to remove all the acetic acid, and that impure sodium arsenate containing some carbonate had been used from which to obtain the arsenic. None of these materials was apparently present in sufficient amount to cause any foliage injury, — a view sustained by the results later.

The solubility of the sample in water was .07 per cent on standing twenty-four hours, and it required an hour for complete settling.

None of the materials showed on analysis the presence of impurities of such kinds and in such amounts as to make injury to the foliage from this cause at all probable.

As a commercial neutral lead arsenate could not be obtained which did not contain a large amount of the acid arsenate also, tests of such a material were not made.

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[1] See Holland and Reed, *loc. cit.*, p. 203.

Application.

The trees used were the apple, cherry, peach, pear, plum and elm. The materials were applied in the same way in all cases, being thoroughly mixed with the proper amount of water just before using. With the acid pastes, 3 pounds in 50 gallons of water, and with the powder, $1\frac{1}{2}$ pounds, were used, the powder containing approximately twice as much arsenic pentoxide as the pastes. As the neutral arsenate contained much less pentoxide than the acid pastes, 5 pounds 7.6 ounces of it were mixed with 50 gallons of water to provide an amount of arsenic pentoxide in the spray equal to that present in the others. Practically an equal amount of poison was therefore applied in every case.

It has been suggested that injury might be caused by the poison entering the leaf through the stomata. As these are usually more numerous on the lower than on the upper surface, branches were held by the hand in such a position that the spray would reach only one surface of the leaf. Parallel tests for both surfaces were made, one test immediately following the other and on the same tree. The main lines of investigation, though, were with reference to variations of temperature and humidity and of light. Two series were made, one in bright, clear weather, and the other on cloudy days.

The temperature and humidity were obtained from a Hygrodeik manufactured by Andrew J. Lloyd & Co. of Boston, giving both the temperature and relative humidity. These were taken at the tree immediately before applying each spray. The attempt was made to spray each surface of the leaves, both in clear and cloudy weather, for at least every 5° interval between 65° and 95° of temperature, and between 50° and 90° of humidity. To obtain all these combinations, however, proved difficult, and some of them were not obtained until several years had elapsed, though fairly complete series were finally secured.

Application of the sprays was begun in June, continued during July, and a few sprays were put on the trees early in August. The tests were begun in 1912 and ended in 1920. After the spray had been applied, its effect was observed about twice a week for at least two weeks, so that any injury appearing late might not be overlooked.

Adequacy of Experimental Methods.

Three possible sources of error, at least, may have affected this experiment. First, there is the difficulty of a uniform estimation of the amount of injury found. As a check upon this we have the very uniform agreement in observations made at identical and nearly identical temperatures and humidities, not only in the same, but also in different years. The personal equation was reduced as much as possible by having the observations all made by one person. Then, after all, the main dividing line was between injury and no injury, determination of the exact degree of injury being of less importance.

A second source of error was the necessity of using different varieties of the fruit trees, in some cases, in different seasons. If different varieties of the same kind vary in their degree of resistance, the results might be expected to vary also, to some extent. This could not hold for the plum, all tests with this being of the Bradshaw variety, and for the elm, which was always the American elm. With the other trees the results do not indicate, at least, that varietal difference was a factor, though it is generally believed that the Baldwin, for example, burns more easily than the McIntosh. How much the results of these experiments were affected by varietal differences cannot be determined.

The third source of error is the possibility of a difference in the leaves as the season progresses, the later sprays having, perhaps, been applied to leaves which had already begun to "harden." Here, too, the results fail to indicate that this was a factor. Burning occurred as frequently after the late July and early August sprays as following the earlier ones, under similar conditions of temperature and humidity, and it would seem that this possible source of error was of little if any importance.

General Results.

Some general conclusions from the investigation were: —

1. The difference in sensitiveness between the upper and under surfaces of the leaves is so slight as to be negligible. Not more than a dozen cases of difference were observed out of nearly 1,600 applications. In these few the under surface showed the greater injury. Apparently in cases of spray injury, it is not caused by the poison entering the leaf through the stomata.

2. Where insects or fungi had produced holes in the leaves, spray injury was frequently observed around the edges of these holes, while the rest of the leaf was not affected. Whether this injury resulted from a freer access of the poison to the inner leaf cells, or would have resulted in any case, is perhaps uncertain. Such injury was not rated as injury by spraying where the unattacked remainder was not affected.

3. It was frequently the case that injury did not appear until nearly a week after spraying (longer in some cases), and increased in severity later. A branch graded as showing a trace of injury at the end of the first week often increased to "slight" after two or three days, and even to "bad," in a few cases, by the end of the second week. In general, though, the final degree of injury had been reached after about twelve or thirteen days.

4. It is well known that some kinds of foliage are more sensitive to arsenical sprays than others, but details as to this have hitherto been lacking. These tests show that the pear and elm are the most resistant of the trees used in the experiments; that the apple comes next, but is much less resistant; that the cherry comes considerably below the apple in this regard; and that the Bradshaw plum and the peach come some distance below the cherry, and are about equally sensitive, the peach being probably rather the more sensitive of the two.

5. No injury either from the pure or commercial materials was obtained with a combination of the lower temperatures and humidities, but traces of it began to appear as these factors became higher. This indicates that one or both of these affect the leaf in some way so that it becomes more sensitive the higher either one goes, and also that medium high temperatures and medium high humidities act together. The results of this work show that with reasonably good materials injury caused is determined by temperature, humidity and perhaps light. The effects of these are therefore given in greater detail below.

The Effects of Temperature, Humidity and Light.

Pear and Elm. — No case of injury to either of these trees was produced by any of the sprays, even at the highest combinations of temperature and humidity (hereafter written T and H) obtained in the course of the work. It may be remarked, however, that this was not true with Paris green and calcium arsenate, the results with which are not included in this bulletin, both materials seriously injuring the leaves under certain T and H combinations. Combinations as high as T91 H71, T80 H84, and T84 H82 resulted in no injury from lead arsenate, and the conclusion is reached that under any usual combinations of T and H obtainable during the summer months, spraying these trees with any reliable brand of lead arsenate should be entirely safe.

Apple. — Fig. 1 shows the results obtained by using pure acid lead arsenate paste in clear weather. The dots show the T and H points obtained for each test; a circle around the dot indicates that there was no injury; *t* indicates a trace of injury, and *s* indicates slight or "some" injury. Figures in parentheses give the number of tests at the same T and H. A line AB can be drawn across the chart somewhat below the *t* spots, which may be termed the safety line under the conditions of this test. Spraying above the TH limits of this line may not result in injury, as four cases on the chart show, but neither can safety be assured above the line.

Fig. 2 shows the results obtained with the same material applied in cloudy weather. It will be noticed that the lowest humidity was 68°, and that only one high temperature (91°) was met with under the required conditions during the six years the tests were carried on. Apparently, cloudy weather is hardly possible (as is to be expected) with low humidities, and also high temperature tends to dissipate clouds.

So far as can be judged from these tests, there is little real difference in results between clear and cloudy weather, except perhaps at the high humidity end of the safety lines. It would seem that injury begins a little sooner in cloudy than in clear weather at medium T and H, but only slightly so with low T. This is made evident by Fig. 3, where the safety lines only are shown together. Here the cloudy weather line diverges from the other toward the high H end of the diagram, though, after all, only by about 5° at H90.

APPLE — RESULTS OF SPRAYING WITH PURE ACID LEAD ARSENATE.

AB, safety line.

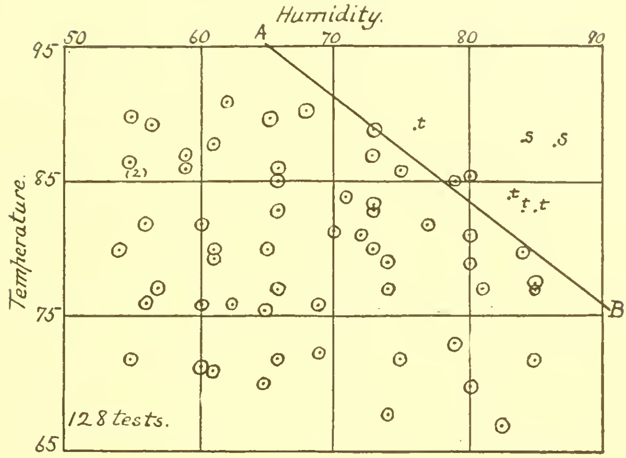

FIG. 1. — Clear weather.

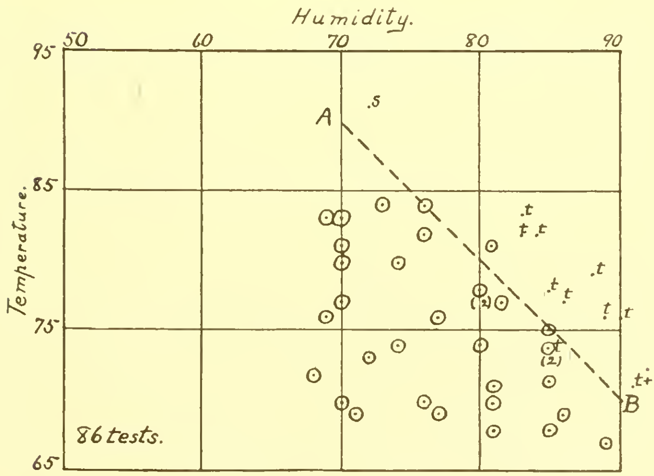

FIG. 2. — Cloudy weather.

With commercial lead arsenate paste the results as shown in Fig. 4 are much the same, though on the whole injury occurs before T and H get quite as high as with the pure paste, particularly at the higher humidities. The clear and cloudy weather lines are more nearly parallel than in the other case.

Apple — Safety Lines for Spraying.

AB, clear weather; CD, cloudy weather.

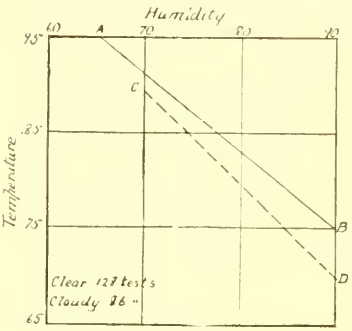

Fig. 3. — Pure acid lead arsenate paste.

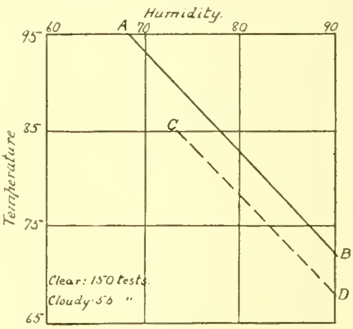

Fig. 4. — Commercial acid lead arsenate paste.

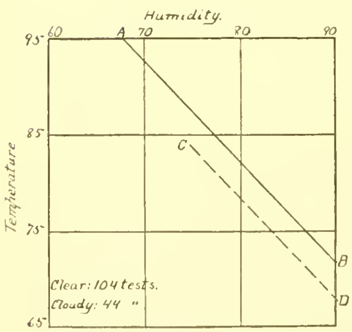

Fig. 5. — Commercial acid lead arsenate powder.

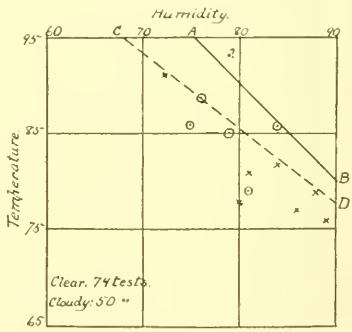

Fig. 6. — Pure neutral lead arsenate paste. Crosses indicate cloudy weather tests with no injury; circles, clear weather tests with no injury.

In the case of commercial lead arsenate powder (Fig. 5), the results differ somewhat, the clear weather safety line beginning at a higher H than in the other cases, but crossing these and running out on H90 at a lower temperature. The total difference, however, is only 4°, so that, after all, there is no great significance in this. The cloudy weather line nearly parallels the clear weather one, and runs about 1° above the commercial paste cloudy weather line.

Results from the use of neutral lead arsenate were rather different from those following the other lead arsenates, this material being apparently the safest of those used. No injury except one doubtful case was found, either

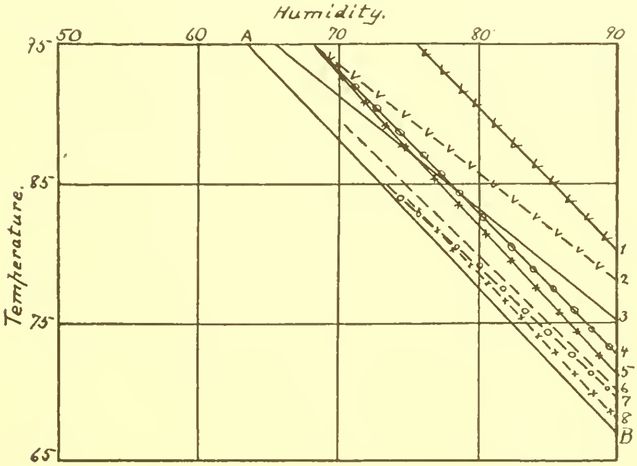

FIG. 7. — APPLE — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, same, cloudy weather; 3, pure acid paste, clear weather; 4, commercial acid paste, clear weather; 5, commercial acid powder, clear weather; 6, pure acid paste, cloudy weather; 7, commercial acid paste, cloudy weather; 8, commercial acid powder, cloudy weather.

in clear or cloudy weather, at the combinations of T and H obtained, and the safety lines were finally placed near the highest records taken. Fig. 6 shows these records and the placing of the safety line with reference to them. So far as can be judged, then, this material is safe to apply under any ordinary combinations of T and H up to the line AB of Fig. 6.

A general conclusion on the apple is that apple foliage is quite resistant to lead arsenate at high temperatures if the humidity is low, and at high humidities if the temperature is low. Thus, spraying appears to be safe at T90 or higher if the H is below 66. With intermediate T and H, however, the two appear to combine, so that at T82, for example, H should not be above 76.

Cherry. — The cherry appears to be much less resistant to injury than the apple. Fig. 8 gives the safety lines for clear and cloudy weather with pure acid lead arsenate paste. Comparing this figure with Fig. 3, we see that temperature is a more active agent with the cherry than the apple, and that this is even more marked in cloudy weather, though with less difference at low temperatures and high humidity.

CHERRY — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

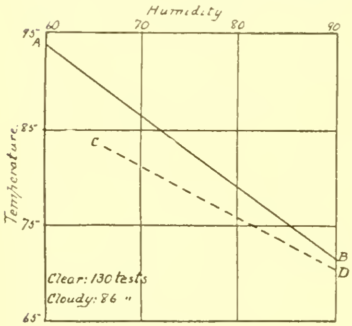

FIG. 8. — Pure acid lead arsenate paste.

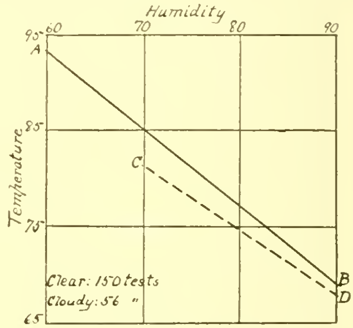

FIG. 9. — Commercial acid lead arsenate paste.

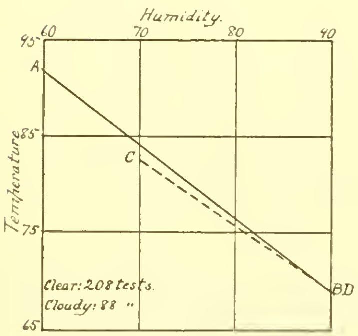

FIG. 10. — Commercial acid lead arsenate powder.

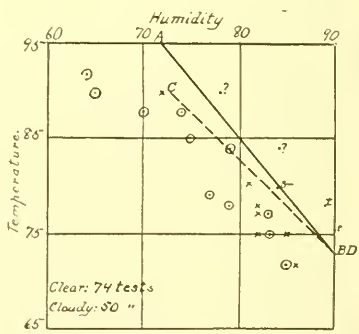

FIG. 11. — Pure neutral lead arsenate paste. Crosses indicate cloudy weather tests with no injury; circles, clear weather tests with no injury.

With commercial acid lead arsenate paste (Fig. 9) the safety lines are very similar to those given in Fig. 8, though a little lower. The difference is insignificant, however. With the commercial acid lead arsenate powder (Fig. 10) the results are also similar, but there seems to be less difference between clear and cloudy weather in producing injury.

The tests with the neutral lead arsenate paste support those on the apple in indicating higher T and H as necessary to cause burning. In Fig. 11 a few of the actual tests are recorded, those marked by circles being clear weather tests and those by crosses, cloudy weather ones. The two interrogation mark tests were clear weather tests, and whether they were really spray injuries is at least doubtful. The two marked "t" and the "s" were cloudy weather tests.

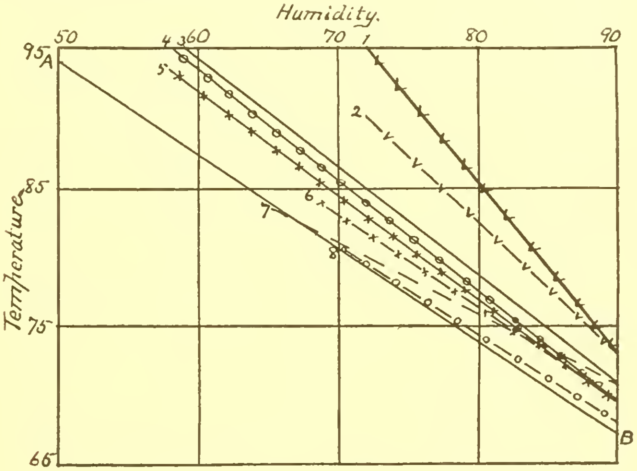

FIG. 12. — CHERRY — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, same, cloudy weather; 3, pure acid paste, clear weather; 4, commercial acid paste, clear weather; 5, commercial acid powder, clear weather; 6, same, cloudy weather; 7, pure acid paste, cloudy weather; 8, commercial acid paste, cloudy weather.

A combination of all the safety lines is given in Fig. 12. The convergence of the lines, in many cases almost to a common point, produces a rather confusing diagram, the significant features being the detached position of the neutral arsenate (1 and 2), the practical parallelism of the other materials in clear weather, and the fact that these are all located at higher H than the same materials in cloudy weather. The arbitrarily placed line AB may be regarded as the safety line for the cherry with any reliable lead arsenate, either in clear or cloudy weather.

A general study of the results obtained by spraying the cherry indicates that this tree is more sensitive to high temperatures where H is low than the apple, while at high humidity with low T it is, on the whole, more resistant. In both fruits the general agreement in each case of the various acid pastes and the noticeable way in which the neutral arsenate stands apart from the others are very marked.

Plum — Safety Lines for Spraying.

AB, clear weather; CD, cloudy weather.

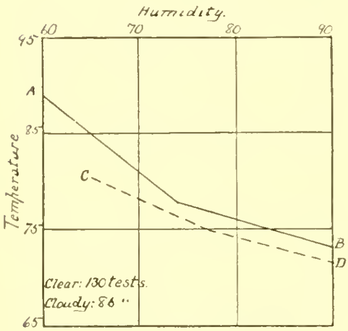

Fig. 13. — Pure acid lead arsenate paste.

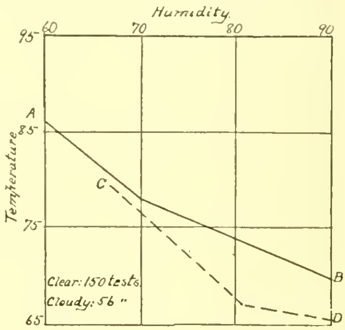

Fig. 14. — Commercial acid lead arsenate paste.

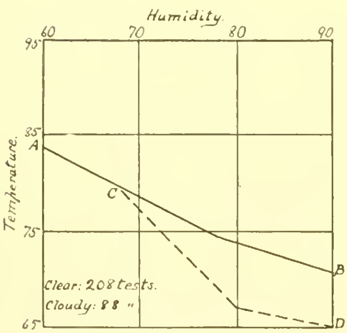

Fig. 15. — Commercial acid lead arsenate powder.

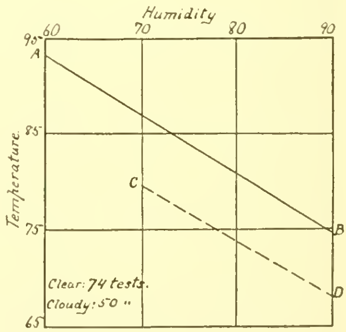

Fig. 16. — Pure neutral lead arsenate paste.

Plum. — The facts obtained here apply only to the Bradshaw plum. The results of the tests of pure acid lead arsenate paste in clear and cloudy weather are given in Fig. 13, and show at once that the resistance of this tree to arsenical sprays is much less than that of the cherry. An additional feature, here first met with in the work, is the fact that the safety lines are not straight but "elbowed." It would seem from the evidence available that in the case of the plum a combination of medium high T and H becomes dangerous more quickly as these increase than with the cherry or apple. This "elbow" is also shown in Fig. 14 giving the safety lines with the commercial paste. Here the lines run on lower T and H, and in cloudy weather humidities above 80, even with low T, are dangerous. A somewhat similar result following the use of the powder is given in Fig. 15 in the case of cloudy weather. The clear weather results differ only slightly from those with the paste.

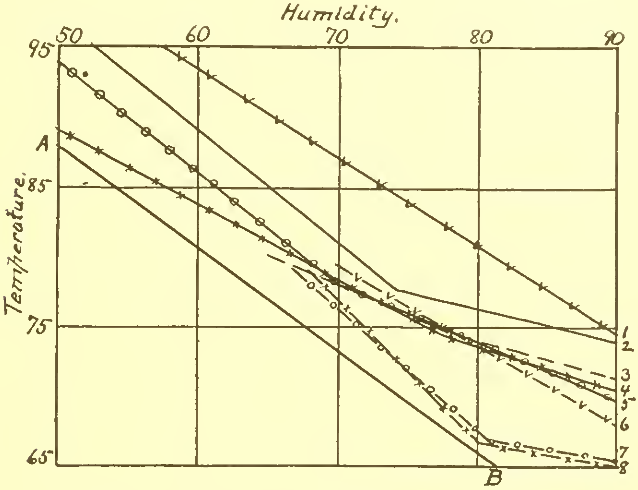

Fig. 17. — Plum — Safety Line for All Lead Arsenates. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, neutral lead arsenate, clear weather; 2, pure acid paste, clear weather; 3, same, cloudy weather; 4, commercial acid powder, clear weather; 5, commercial acid paste, clear weather; 6, neutral lead arsenate, cloudy weather; 7, commercial acid paste, cloudy weather; 8, commercial acid powder, cloudy weather.

The neutral arsenate, as in the case of the other trees, is much safer than the acid arsenates, though the cloudy weather line (Fig. 16) for the first time drops to run about along with those of the acid pastes in clear weather. No "elbow" appears for the neutral arsenate.

In Fig. 17 the various safety lines are brought together on one chart. The striking point shown here is that in the high humidities of cloudy weather the commercial paste and powder, closely following each other, drop far below the other lines. On the whole, the line AB should mark a safety line, however, at or below which spraying on the plum should be safe under any combinations of T and H with any reliable material.

General conclusions as to the plum, so far as the evidence goes, are: first, that this tree is far less resistant to arsenicals under certain conditions of T and H than the cherry; second, that in clear weather it is less sensitive to high humidities than to high temperatures when the other factor is low; third, that this last does not hold for the acid paste and powder in cloudy weather; and fourth, that again the neutral lead arsenate is the safest of the materials used.

PEACH — SAFETY LINES FOR SPRAYING.

AB, clear weather; CD, cloudy weather.

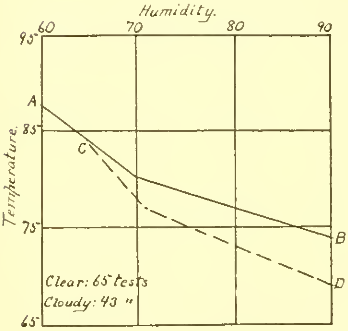

Fig. 18. — Pure acid lead arsenate paste.

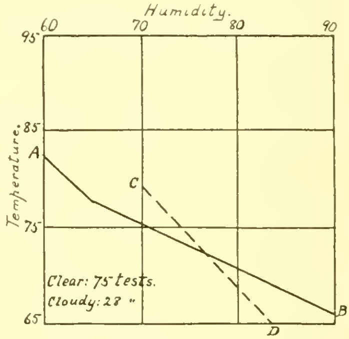

Fig. 19. — Commercial acid lead arsenate paste.

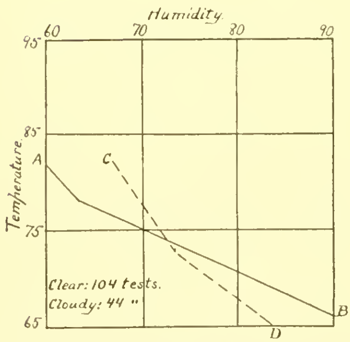

Fig. 20. — Commercial acid lead arsenate powder.

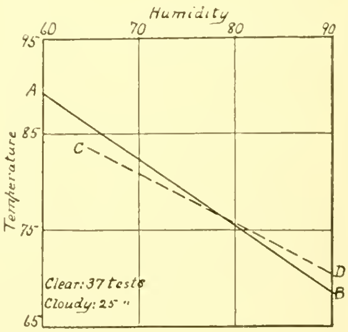

Fig. 21. — Pure neutral lead arsenate paste.

Peach. — The results of the experiments on the peach are, on the whole, very similar to those obtained from the plum. In general, the safety lines are very close, and the conclusion reached that the plum is somewhat more resistant than the peach is based mainly upon experiments with other arsenicals. There seems to be less difference at the T and H limits of the charts than was shown for the plum. In three sets of tests (Figs. 19, 20 and 21) the clear and cloudy weather lines cross, but the difference is not very great. The neutral arsenate fails to make quite as good a showing as with

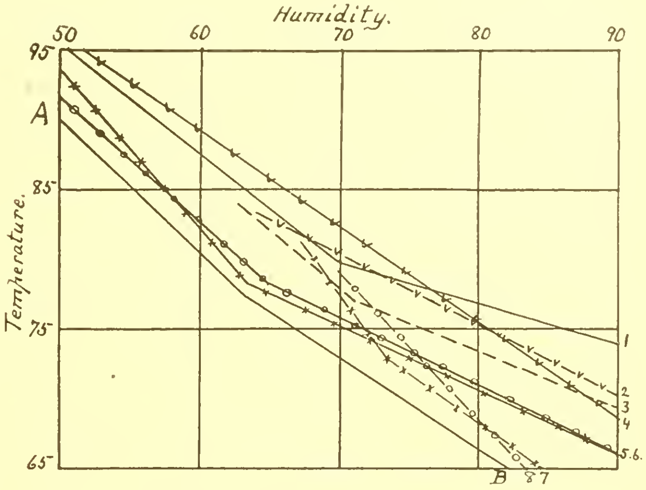

FIG. 22. — PEACH — SAFETY LINES FOR ALL LEAD ARSENATES. AB, safety line for spraying with any reliable lead arsenate under all weather conditions; 1, pure acid paste, clear weather; 2, neutral lead arsenate, cloudy weather; 3, pure acid paste, cloudy weather; 4, neutral lead arsenate, clear weather; 5, commercial acid paste, clear weather; 6, commercial acid powder, clear weather; 7, same, cloudy weather; 8, commercial acid paste, cloudy weather.

the other trees, but is, nevertheless, still the best for the greater part of its range. "Elbowing" of the safety lines is again in evidence except with the neutral arsenate and the commercial acid paste in cloudy weather. Perhaps in this last case a larger number of tests (it was not possible to make very many) might change the path of this line somewhat. Comparison of Figs. 17 and 22 shows that the peach appears to resist injury slightly better than the plum at high T and low H, while at high H and low T the two are about alike.

It should be noted that in Figs. 7, 12, 17, 22 and 23 the chart is extended 10° lower in humidity than the others to show the paths of the safety lines in this added area. To make comparisons with the others, reading of these charts should begin, not at H50, but at H60.

In order to obtain some idea of the relative resistance of the apple, cherry, plum and peach to arsenical sprays, Fig. 23 has been prepared, the material used in each case being the pure acid lead arsenate paste applied in clear weather. The elm and pear are not included, for as already stated, no injury points were obtained. If their safety lines come into the chart at all, they would only cross the upper right square, and probably would not occur unless close to H90 T95.

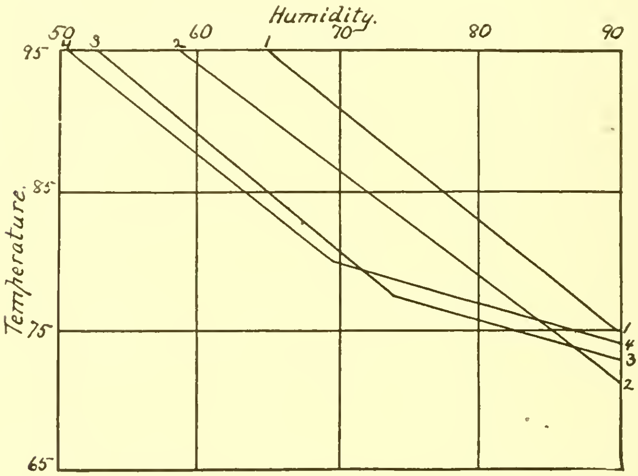

Fig. 23. — Safety lines for spraying with pure acid lead arsenate in clear weather: 1, apple; 2, cherry; 3, plum; 4, peach.

General Conclusions.

An analysis of the effects of temperature, humidity and light given in detail above brings out several features of interest: —

1. The neutral lead arsenate used, even though it was not entirely pure, proved the safest of the materials in clear weather, and in most cases was better even in cloudy weather than the others.

2. The clear weather spraying is safer than the cloudy weather, though the difference generally is not great.

3. The indication is that spraying at high temperatures can be done safely if the humidity is low.

4. Spraying can be carried out safely at high humidities if the temperature is low, though the humidity cannot run up as high as the temperature can at the other end of the line. Thus spraying the apple seems to be safe at T90 when H is not over 69, but is not safe at H90 when T is above 67.

5. Between the ends of the safety lines of the charts, *i.e.*, with medium T and H, both seem to have an influence.

6. With the apple and cherry the safety lines are straight, while in the plum and peach most of them "elbow," indicating that the T and H fac-

tors are more powerful at medium values, or when both act in medium amounts, than where either one is low, even though the other be high.

7. In the case of the plum the elbow is between H70 and H80, while with the peach it tends to move back toward lower humidities; or, in other words, the plum seems to be more sensitive to higher humidities than the peach, and also at the extremes of the safety lines to both T and H.

8. From the tests with lead arsenate, the peach and the Bradshaw plum at least appear to have about the same degree of resistance to arsenical sprays.

From the evidence at hand it would seem that, with reliable arsenicals properly made, mixed and applied, injury results from the combination of temperature, humidity and light factors. A high value for either of the first two factors, provided the other is low, indicates probable safety, particularly on sunny days.

Why divergence from these requirements should cause burning has not been brought out by this work. It may be that, as the injury generally appeared only after a week or more, there was some chemical factor at work. With some carbonic acid in the air and heavy dews at night it might be possible that a slow decomposition of the arsenate on the leaves took place, gradually liberating the arsenic and resulting after a time in injury. If this were correct, however, it would seem as though the decomposition of the arsenate would take place when sprays were applied at T and H combinations below the safety line, and cause burning in those cases also. Possibly the leaf differs in its physiological activities under different conditions of light, temperature and humidity, and under some of these is susceptible to influences not effective under others.

The most that can now be said is that this work has failed to answer the question why arsenical sprays sometimes injure foliage, though it has shown that of the four explanations given at the beginning, the first, second and fourth can be rejected, and that the problem is apparently one for the plant physiologist, the chemist, or both working together, to solve. The demonstration of safety limits for spraying can hold good, however, even though the question of why they are located where they are remains unanswered.

BULLETIN No. 208.

DEPARTMENT OF POMOLOGY.

LEAF CHARACTERS OF APPLE VARIETIES.

BY J. K. SHAW.

It is as easy to recognize varieties of apples by their tree characters as by their fruit, yet all fruit growers know varieties by the fruits much better than by the trees. This is doubtless because they come into closer contact with the fruit. They pick, handle and eat the fruit, while contact with the trees is less frequent and intimate. Nurserymen are more familiar with the tree, and many old nurserymen know varieties by the nursery trees better than by the fruit. As trees have been studied less than the fruit, there has been less written about them. Variety descriptions deal mostly with the fruit. John J. Thomas, himself a nurseryman of many years' experience, discussed tree characters at some length in his "American Fruit Culturist," but his work along this line has been given little attention by other writers.

In recognizing varieties, especially with nursery trees, one depends largely on the leaves, and it is our purpose here to discuss the leaf characters by which we may know one variety from another. Characters of the bark, buds, branches and general habit of the trees are very useful, perhaps equal to the leaves, but they will receive only incidental mention here, being reserved for further study and later discussion.

In order to talk understandingly about the leaves we must have names for their different parts. These are shown in Fig. 1, which is largely self-explanatory. The leaf is first divided into three parts: stipules, petiole and blade. About one-third of the blade next to the petiole is called the base, and similarly about one-third of the other end, the apex; beyond this is the narrow point called the tip. The midrib is a continuation of the petiole to the tip of the leaf. The saw-like notches along the edge of the leaf are called serratures or serrations, and are of the greatest importance, being rarely exactly alike in two varieties.

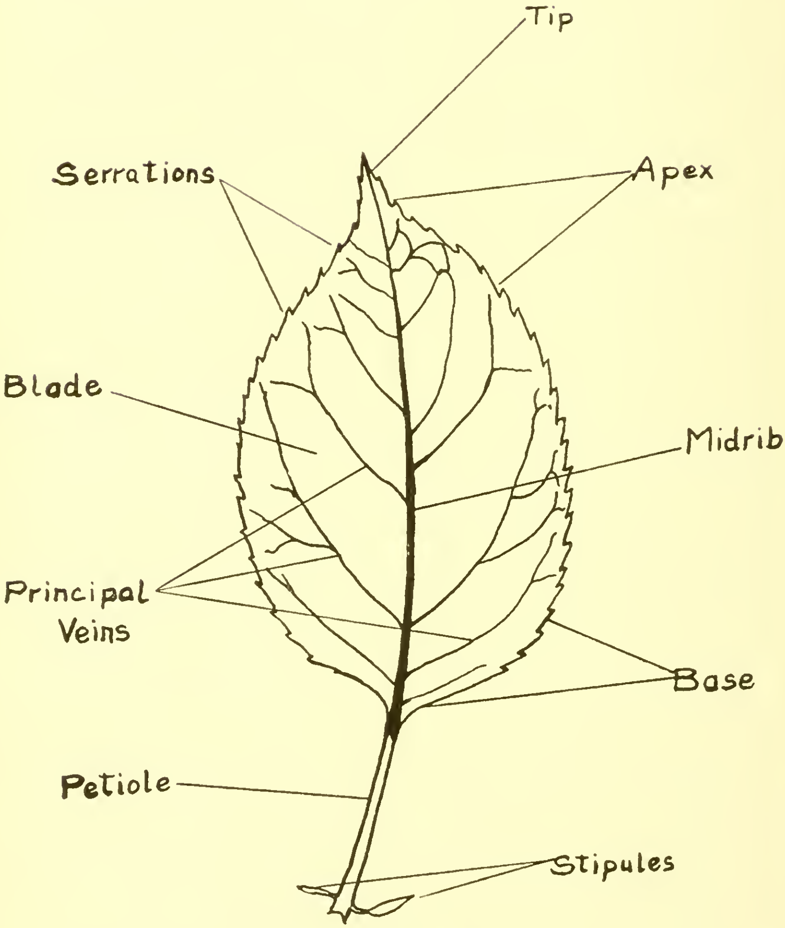

FIG. 1. — Diagram of apple leaf, showing parts.

Which are the Characteristic Leaves.

The leaves on any tree can be divided into two groups: (1) the single leaves coming out on the current season's growth; and (2) the rosette leaves coming out of buds formed the previous season, *i.e.*, on wood of last year's growth. *The latter should be discarded, and study and attention centered on the single leaves on the current season's growth.* Leaves that have been injured by lice or other insects or by scab spots are of little value for identification purposes. Leaves on shoots in the interior of the tree should be avoided. *Study the well-developed uninjured leaves usually found along the middle of the season's growth.* Leaves on trees that are poorly nourished are often undersized and yellowish. Such leaves are not typical and should be observed with caution.

Typical leaves are found on healthy uninjured trees that are making vigorous but not excessive growth. Inasmuch as one requires the leaves of the current season's growth, little progress can be made in leaf study until considerable growth has been made. The most favorable period is from July 1 until October 1. To one familiar with leaf characters this period may be extended somewhat.

What to Look at.

To the beginner in leaf study the leaves of all varieties will look alike. Close and repeated observation will reveal differences that are peculiar to the different varieties. It is our purpose here to discuss the various parts of the leaf and how they differ in different varieties. (See Fig. 1.)

The Petiole.

The petiole or stem of the leaf is sometimes characteristic of the variety, though it is of minor importance. Wealthy has a rather long, slender petiole, while that of McIntosh is usually short and stout. The angle which the petiole forms with the shoot on which it grows is often helpful in recognizing varieties. In the Spy the angle is sharp, that is, the leaf is said to be upright; while in the Rhode Island Greening it is broad or spreading. This character is correlated in all varieties with the form of the top. The Spy has an upright head, while the Rhode Island Greening is distinctly spreading. This character of the head or form of the tree is quite well known to fruit growers, but few are aware that in an unknown variety the form of the top can be foretold with considerable accuracy from the leaf angles on a one-year whip.

The Stipules.

The stipules located at the base of the petiole have a certain value in variety identification. They vary in size and shape and in the degree to which they persist. In all or nearly all varieties they are likely to fall by late summer or early fall, especially if there is a good deal of dry weather.

The Blade.

Size. — Coming now to the blade we find the most dependable characters for variety identification. Let us first consider the size of the leaf blade. This, of course, varies considerably with the vigor of the tree. Trees in a sod orchard making little growth will have much smaller leaves than will the same variety growing under cultivation and making a vigorous growth. Leaves well exposed to the sun will be smaller than those growing in shade, as in the interior of the tree. With these reservations in mind, we may say the Jonathan (Fig. 17) has a small leaf, while Rhode Island Greening (Fig. 4) and King (Fig. 24) have large leaves; Wealthy (Fig. 7) is a little smaller than Baldwin (Fig. 8); and McIntosh (Fig. 3) a little larger than Wolf River (Fig. 12).

Shape. — Next we may consider the shape or outline of the leaf. This may vary in different varieties in two ways: in relative length and width, and in the width of the base and apex. Winter Banana (Fig. 10) is relatively long and narrow, while Baldwin (Fig. 8) is relatively short and broad. An example of the second is found in comparing Wolf River (Fig. 12), which is narrow at the base and apex, with McIntosh (Fig. 3), which is broad at the base and apex. This difference is especially valuable in distinguishing between Oldenburg (Fig. 6) and Wealthy (Fig. 7), the former being much broader at the base and apex than the latter.

Tip. — The narrow tip called the point is of some value, being larger and more slender in some varieties, usually those with a narrow apex, than in others.

Folding. — Next we may consider the various types of bending and folding which may appear in the leaf blade. The blade may be flat as in Gravenstein (Fig. 2) and Wealthy (Fig. 7), or it may be folded to a greater or less degree as in Baldwin (Fig. 8) or Wagener (Fig. 15). The last two varieties exhibit different types of folding, it being broad, saucer-shaped or boat-shaped in the Baldwin, and much narrower and more pronounced in the Wagener. Leaves of a given variety may show this character in varying degree according to condition; the folding is more pronounced in periods of dry, sunny weather than it is during cloudy or rainy periods. Jonathan, as shown in Fig. 17, shows only moderate folding, but at times it may show very pronounced folding, — sometimes more than any variety illustrated here. Nevertheless, it is a most valuable character in the identification of varieties. The peculiar saucer-shaped folding of the Baldwin is always seen in greater or less degree in a considerable proportion of the single leaves on the tree, and with one or two other peculiarities will serve to distinguish this variety from all others.

Next we may consider the bending or waving of the leaf edge. Flat leaves do not often show this, although it appears quite noticeably in Oldenburg and Wealthy, neither of which are folded very much. Some folded leaves are very distinctly waved, as Wagener (Fig. 15), Hubbardston (Fig. 22) and Tolman (Fig. 27), while others show it but little, as Baldwin (Fig. 8), Roxbury Russet (Fig. 9) and Winter Banana (Fig. 10).

A third type of bending or folding of the leaf blade is seen in the bending backward or reflexion of the midrib. Pronounced reflexion of the midrib is not common in flat leaves, but is the usual thing in strongly folded leaves if the folding is of the narrow type. Thus Baldwin (Fig. 8) and Roxbury Russet (Fig. 9) are not reflexed, while Grimes (Fig. 20) and Wagener (Fig. 15) are strongly reflexed.

Serratures. — Probably the most dependable leaf character for identifying varieties is the nature of the serratures along the edge of the leaf. They are sharp in Rhode Island Greening (Fig. 4) and dull in Wolf River (Fig. 12) and Wealthy (Fig. 7). Other varieties are intermediate between these extremes, but every variety is peculiar to itself and different from other varieties. In Rhode Island Greening (Fig. 4) the serratures are distinct or well separated, while in Gravenstein (Fig. 2) and Baldwin (Fig. 8) they are set close together or indistinct. They vary in depth also, and in some varieties they are straight, as in Rhode Island Greening, while in Baldwin they are more or less curved or sickle-shaped. The last peculiarity, together with the saucer-shaped folding referred to above, serves to distinguish Baldwin from all other varieties known to the writer. If one leaf is laid upon another so that the serratures of both can be seen and carefully compared, the observer with some experience can very often tell quite positively whether the leaves represent one variety or two varieties.

Texture. — The veins of the leaves divide and subdivide until they form a network all over the surface of the leaves. This network is coarser in some varieties than in others. There are other peculiarities in the veining hard to describe in words, but evident and distinct in the leaves. These peculiarities taken together are spoken of as texture. The texture of Rhode Island Greening (Fig. 4) is very different from that of McIntosh (Fig. 3). Comparisons of other varieties will show differences in texture difficult to picture in words, but of much value in recognizing varieties.

Pubescence. — All varieties have more or less growth of short hairs over the under surface. Those having an abundant growth of these hairs are said to be pubescent or "woolly." This is not shown very clearly in the figures, but may be seen by observing the leaves themselves. Ben Davis and Jonathan are examples of "woolly" leaves, while Rhode Island Greening shows very little of this growth. This hairy growth is sparse on Baldwin and more abundant on Hubbardston and McIntosh.

In some varieties the surface of the leaves is smooth and shining, while at the other extreme are some varieties that appear rough or dull. This is correlated with hairiness or woolliness of the surface, the smooth and shining leaves having few hairs, while the rough or dull ones have many.

Thickness. — Varieties differ also in the thickness of the leaves. McIntosh and Wealthy have relatively thick, stiff, rigid leaves, while those of Rhode Island Greening, Grimes and Fall Pippin seem thinner and less rigid to the touch.

Color. — All apple leaves are, of course, a deep rich green in color. The shade of green depends a good deal on the vigor of the trees, being deeper in vigorous trees, and a paler, more yellowish green in trees making little growth. There are also varietal differences in color. In Rhode Island Greening and in all green-fruited varieties the color is a rich, clear green; in varieties that have much red in the color of the fruit the leaves are a deeper green with a slight bluish or purplish cast. This is seen in McIntosh. Yellow Transparent has leaves of a yellowish green cast. These differences in leaf color are not pronounced, and as stated above vary with the condition of the trees, but they are very helpful in recognizing varieties.

In distinguishing two or more varieties which are mixed in the nursery row, one may often find some peculiarity of a certain variety present at the particular time at which the observation is made, which serves to distinguish that variety with ease and certainty. For example, in separating out Wolf River trees in a mixture with McIntosh it was observed that, at the time the Wolf River leaves were beginning to turn yellow and perhaps one-third of them had fallen, the McIntosh leaves showed very little yellowing and few if any had fallen. By observing this difference it was possible to separate the two varieties with the greatest ease and certainty. Yet at an earlier period this difference would not have been present. In the late summer the Yellow Transparent leaves near the tips of the shoots frequently show a spiral folding that displays plainly the under side of a portion of the leaf. When this peculiarity is shown it is possible to recognize a Yellow Transparent tree as far as it can be seen. It is the usual thing in separating mixed varieties to fix on some one character by which the varieties can, at that particular time and place, be positively distinguished one from the other.

Classification of Varieties.

Twenty-six varieties of more or less importance in Massachusetts have been selected for illustration and description in this bulletin. The following key is arranged to show, as well as possible, the differences by which these varieties may be distinguished. It is not thought that this key will enable one to trace out unknown varieties, but it may help in orchard and nursery studies of the leaves of these varieties. A few tree characters are mentioned with the hope that they may be helpful.

A. Varieties important in Massachusetts.
- 1. Leaves large, broad, flat or only slightly folded.
  - (*a*) Sides not waved or only very slightly so.
    - *Gravenstein.* — Leaves broad oblong; serrations dull, shallow, regular; branches broadly ascending; bark dark yellowish. (Fig. 2.)
    - *McIntosh.* — Leaves broad oval, base often cordate, edges often slightly folded; serrations dull and shallow, especially at base. (Fig. 3.)
    - *Rhode Island Greening.* — Serrations very sharp and distinct. (Fig. 4.)
  - (*b*) Sides more or less waved.
    - *Red Astrachan.* — Leaf waves "crinkly" or wrinkled, not reaching to midrib. (Fig. 5.)
    - *Oldenburg.* — Leaves broad at base and apex; shoots few and stout. (Fig. 6.)
    - *Wealthy.* — Leaf relatively narrow at base and apex; midrib often tending to spiral form or reflexed at tip. (Fig. 7.)

A. Varieties important in Massachusetts — *Concluded.*

2. Leaves more or less distinctly folded.

(*a*) Folding "saucer-shaped" or broad U-shaped.

Baldwin. — Leaves broad, distinctly saucer-shaped; serrations sharp, close set and usually curved. (Fig. 8.)

Roxbury Russet. — Serrations distinct and only moderately sharp; bark olive green. (Fig. 9.)

Winter Banana. — Leaves rather long and narrow; serrations regular and dull; branches long and slender, yellowish. (Fig. 10.)

(*b*) Folding narrow U-shaped.

(1) Serrations dull.

Williams. — Waves large, coarse; serrations uniform; growth open; bark yellowish. (Fig. 11.)

Wolf River. — Leaf only moderately folded, oval, narrowing at base and apex; serrations coarse, dull. (Fig. 12.)

Yellow Transparent. — Leaves broad at base and rather narrow at apex; serrations uniform, shallow. (Fig. 13.)

(2) Serrations at least moderately sharp.

Delicious. — Leaves narrow at apex; serrations coarse and distinct. (Fig. 14.)

Wagener. — Leaves strongly folded; midrib much reflexed; shoots stout with large buds. (Fig. 15.)

Northern Spy. — Leaves sometimes little folded, upright; serrations sharp; shoots upright; bark russet with many small dots. (Fig. 16.)

B. Varieties of minor importance in Massachusetts.

1. Leaves usually only slightly folded, serrations rarely sharp.

(*a*) Leaves small, coarsely and irregularly serrate.

Jonathan. — Leaves very small, narrow at base and apex, sometimes folded; tree slender, of open habit. (Fig. 17.)

King David. — Leaves narrow at base but wider at apex; tree strong and vigorous. (Fig. 18.)

Stayman. — Leaves nearly round, spur leaves and some shoot leaves sharply serrate; tree vigorous. (Fig. 19.)

(*b*) Leaves medium-sized, serrations rather fine and regular.

Opalescent. — Leaves sometimes slightly waved, rather narrow at apex; bark of shoots very smooth. (Fig. 20.)

2. Leaves distinctly folded and waved.

(*a*) Serrations distinct and rather sharp.

Fall Pippin. — Leaves long, sharply and distinctly serrate; tree vigorous. (Fig. 21.)

Hubbardston. — Serrations moderately sharp; midrib reflexed; bark olive green. (Fig. 22.)

Grimes. — Serrations sharp and distinct; midrib reflexed. (Fig. 23.)

Tompkins King. — Tree vigorous with long stout shoots, does not branch freely. (Fig. 24.)

(*b*) Serrations not sharp but rather dull.

Ben Davis. — Leaves rather narrow, grayish and woolly. (Fig. 25.)

Esopus Spitzenburg. — Serrations dull and regular; midrib usually only slightly reflexed. (Fig. 26.)

Tolman. — Leaves narrow at base and strongly waved; serrations only moderately dull. (Fig. 27.)

The varieties in the foregoing classification are illustrated in the following pages. These cuts are approximately two-thirds life size. While, as stated in the text, the size of the leaves may vary with cultural conditions, yet these may be taken as fairly representative, and are comparable one with another.

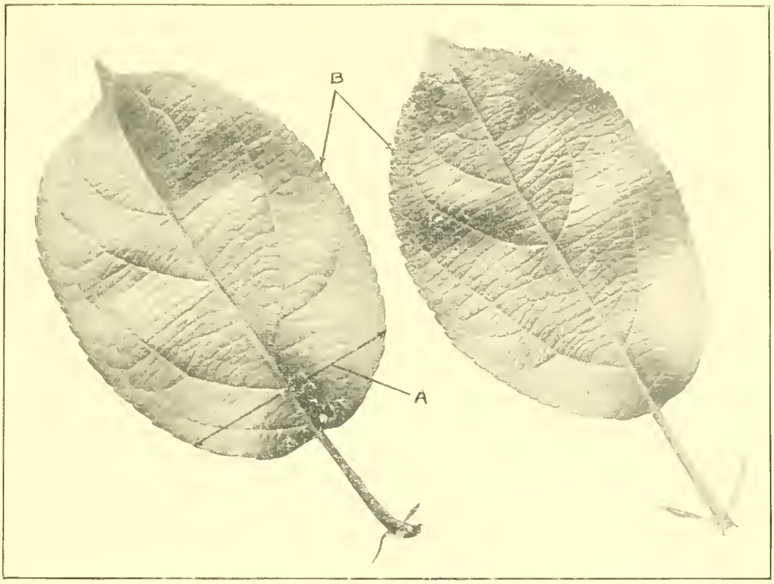

Photo by R. L. Coffin.

FIG. 2. — GRAVENSTEIN. Blade large, flat, rounded or rather narrow at base (A); serrations moderately sharp and shallow (B), fairly regular.

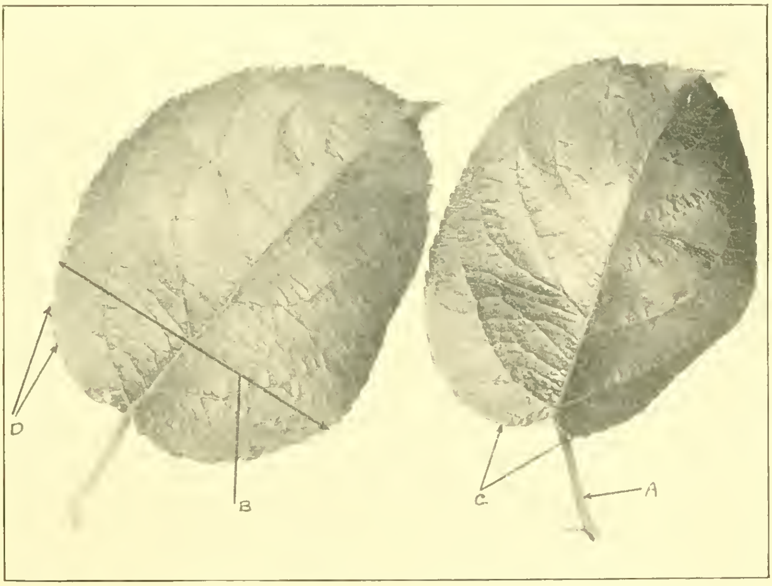

FIG. 3. — McINTOSH. Petiole short (A); blade large, flat or slightly folded near edge, broad (B) and heart shaped (C) at base, deep bluish green; serrations rather dull and shallow, especially at base (D).

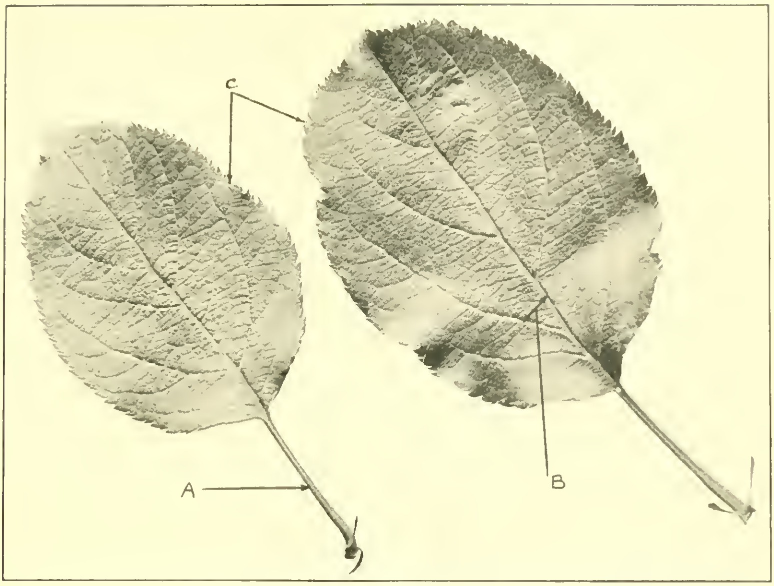

Photo by R. L. Coffin.

FIG. 4. — RHODE ISLAND GREENING. Petiole long (A); blade large, flat, deep clear green; vein angle sharp (B); serrations very sharp, deep and distinct (C).

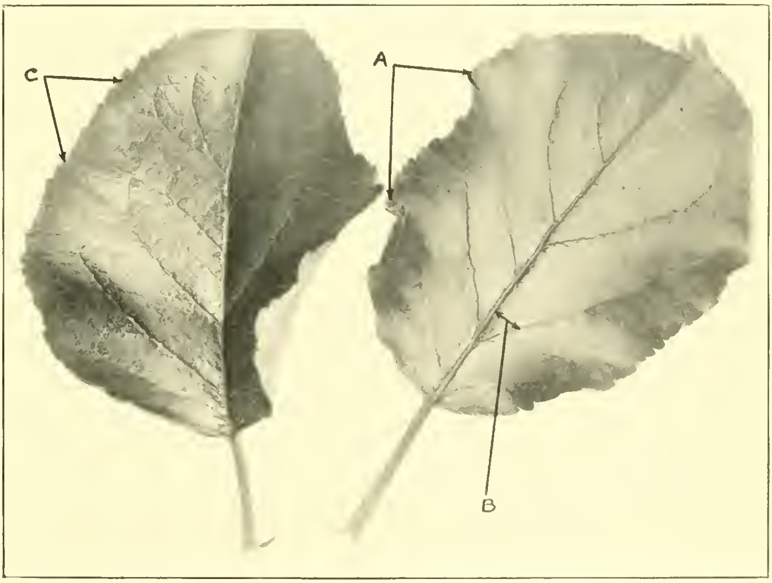

FIG. 5. — RED ASTRACHAN. Blade large, broad, flat, with waved and wrinkled edges (A); vein angle sharp (B); serrations dull and irregular (C).

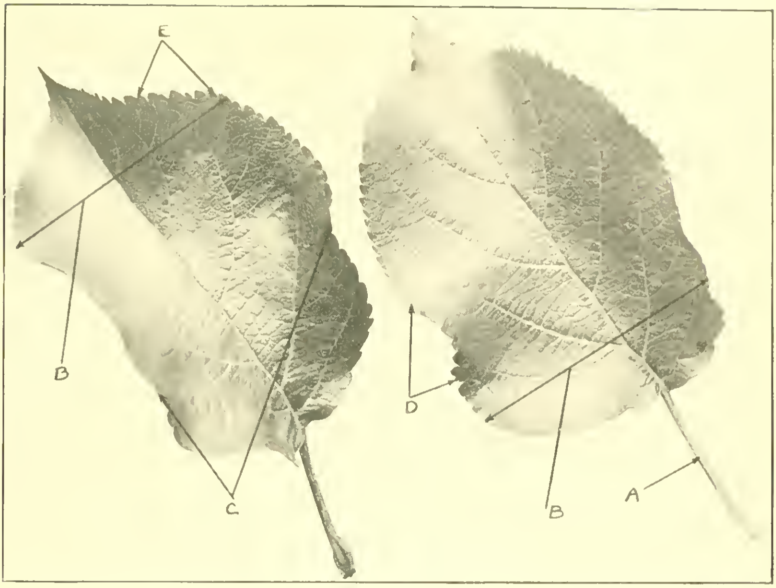

Photo by R. L. Coffin.

FIG. 6. — OLDENBURG. Petiole long (A); blade above medium to large, broad at base and apex (B), somewhat folded (C), and waved (D); serrations moderately sharp and irregular (E).

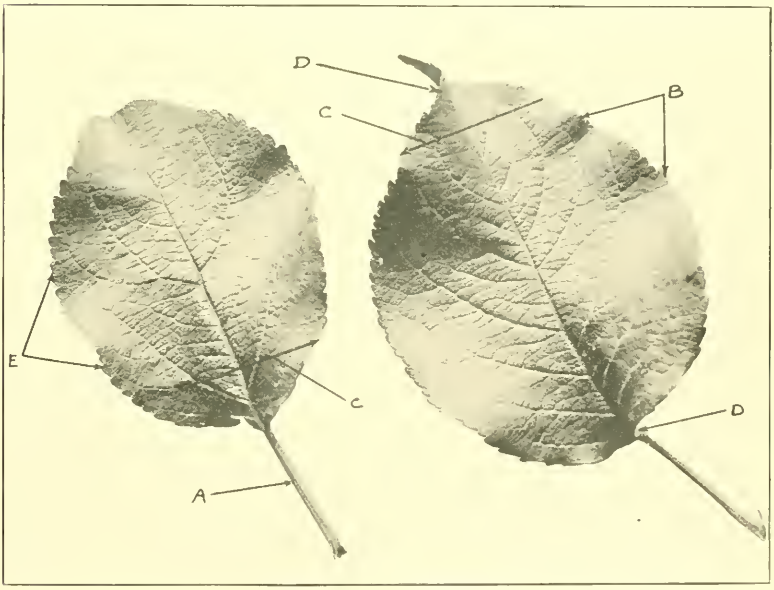

Photo by R. L. Coffin.

FIG. 7. — WEALTHY. Petiole long (A); blade moderately large, flat, with waved edges (B), narrow at base and apex (C); midrib reflexed or spiral (D); serrations rather dull (E).

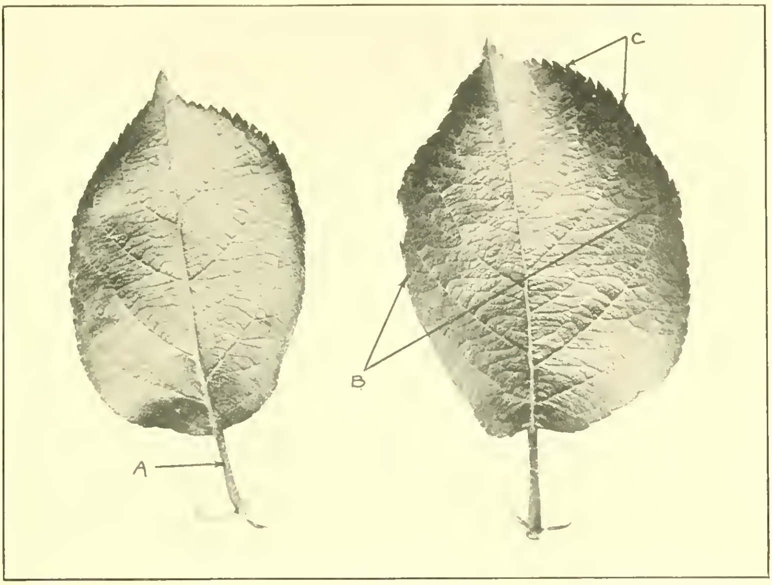

Photo by R. L. Coffin.

FIG. 8. — BALDWIN. Petiole short (A); blade large, broad, with "saucer shaped" folding (B); serrations sharp, close set, usually curved (C).

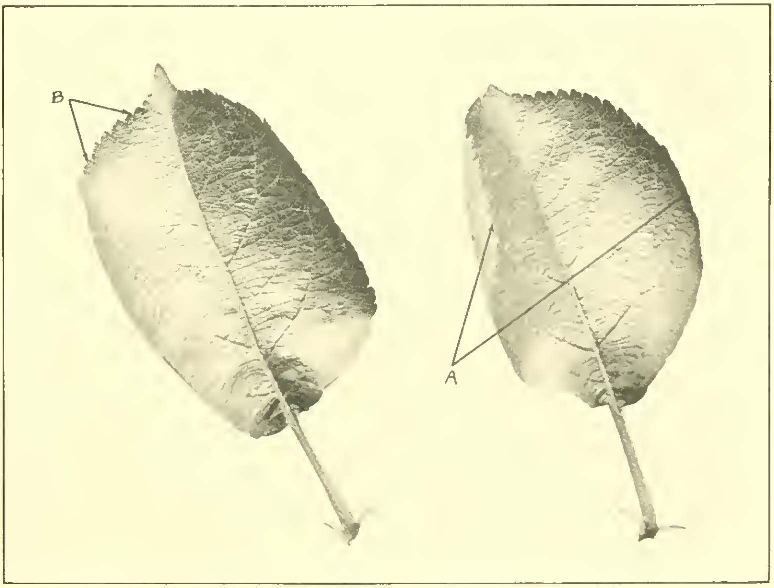

Photo by R. L. Coffin.

FIG. 9. — ROXBURY RUSSET. Blade large, broad, with "saucer shaped" folding (A); serrations not sharp nor curved (B).

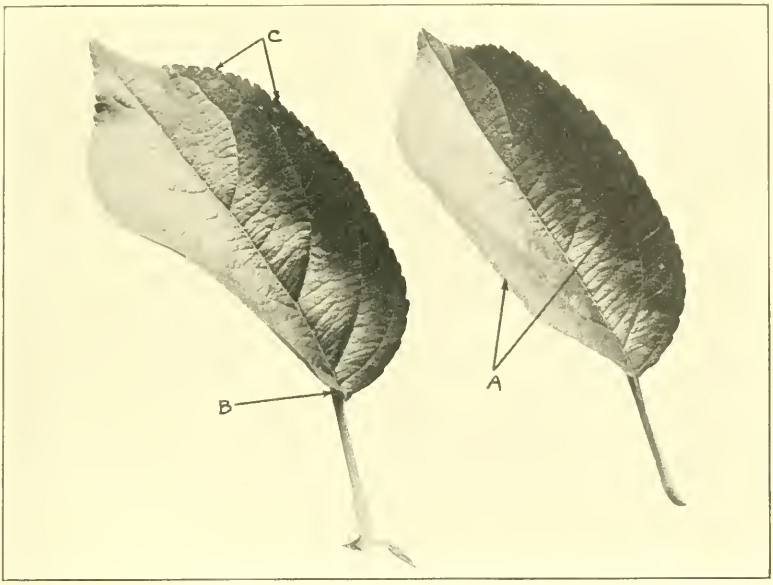

Photo by R. L. Coffin.

Fig. 10. — Winter Banana. Blade medium size, rather long and narrow, folded (A); midrib bent at base (B); serrations rather dull and shallow (C).

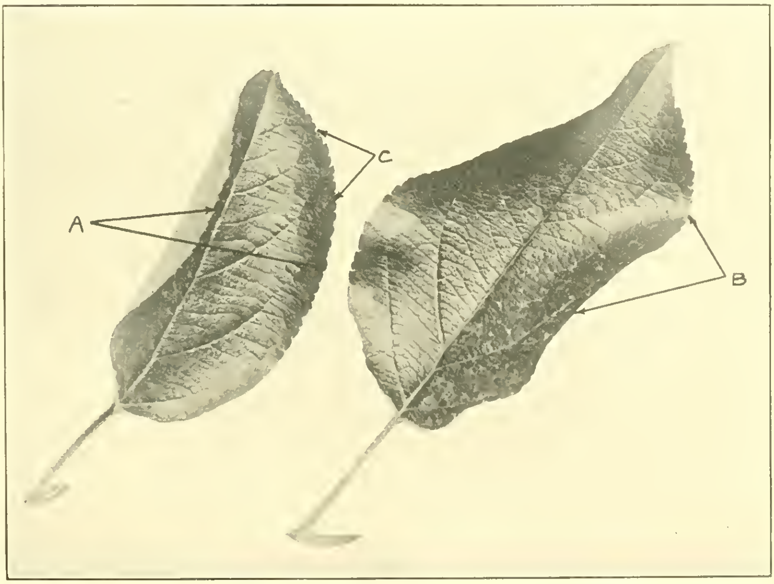

Fig. 11. — Williams. Blade medium size, folded (A) and often coarsely waved (B); serrations rather dull and quite regular (C).

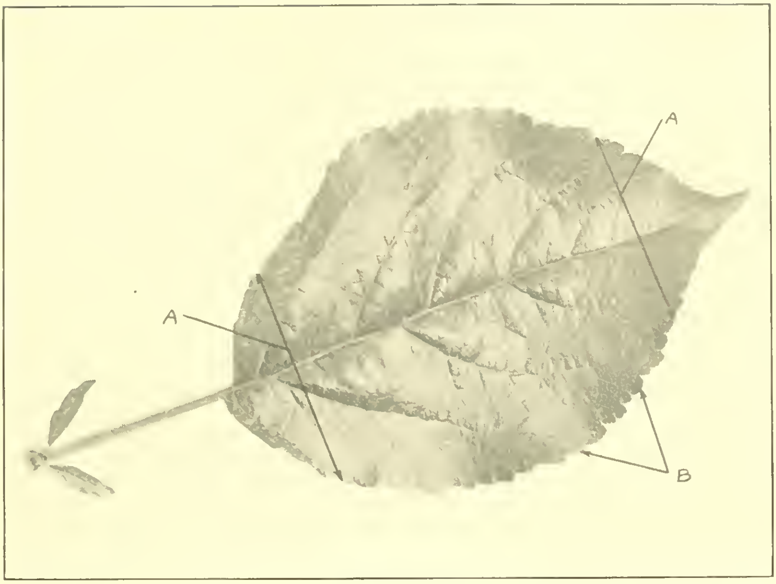

Fig. 12. — Wolf River. Petiole long; blade often only slightly folded, narrow at base and apex (A); serrations coarse and dull, often double (B).

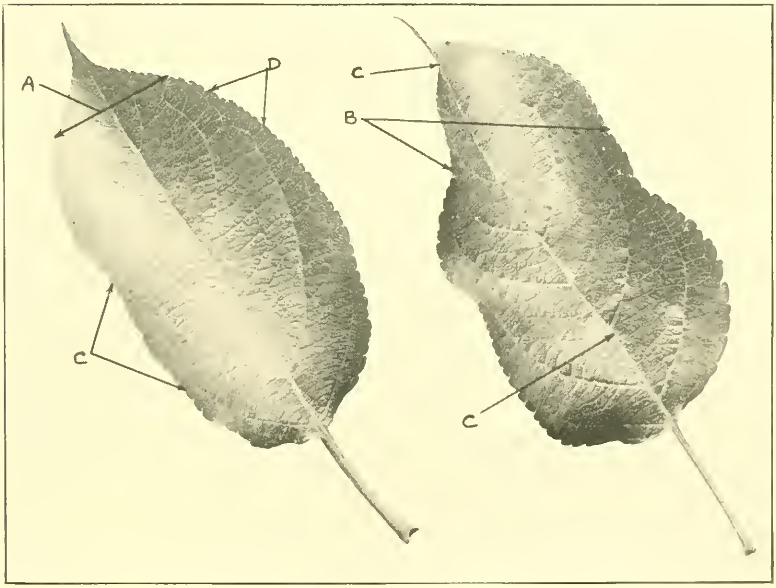

Photo by R. L. Coffin.

Fig. 13. — Yellow Transparent. Blade medium size, rather broad at base and narrow at apex (A), more or less folded (B), more or less waved, and often spiral (C); serrations rather dull, shallow and quite regular (D).

Fig. 14. Delicious. Blade medium size, apex narrowing to point (A), partly folded (B); serrations moderately sharp, coarse and rather irregular (C).

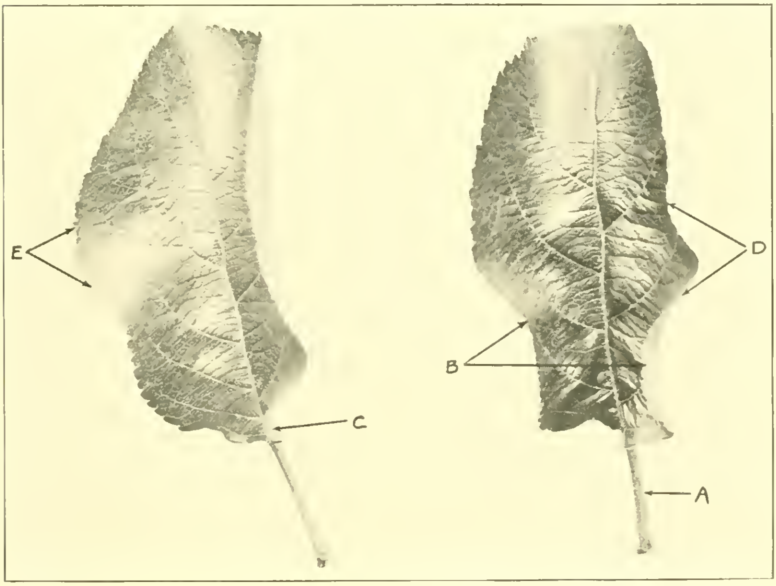

Photo by R. L. Coffin.

Fig. 15.—Wagener. Petiole short and stout (A); blade large, long and rather narrow, strongly folded (B), reflexed (C), and waved (D); serrations rather sharp, coarse and distinct (E).

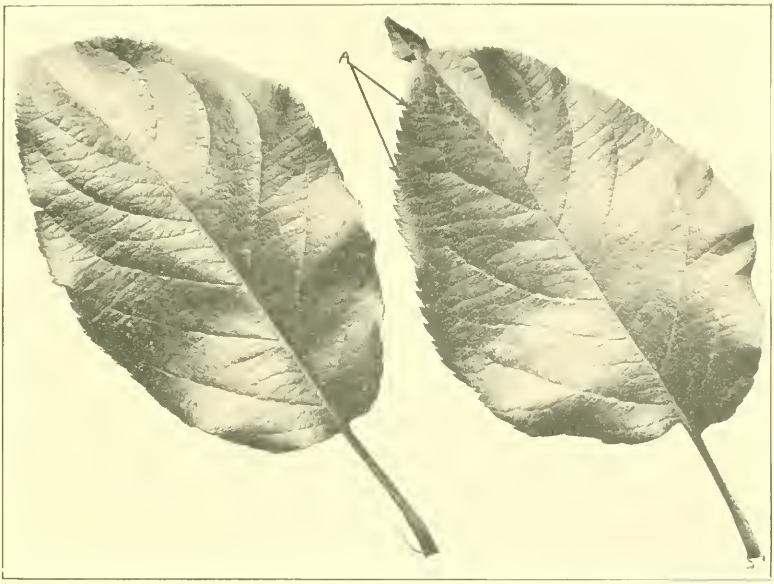

Photo by R. L. Coffin.

FIG. 16. — NORTHERN SPY. Blade large, somewhat folded and waved, upright, often somewhat reflexed; serrations sharp, often curved (A).

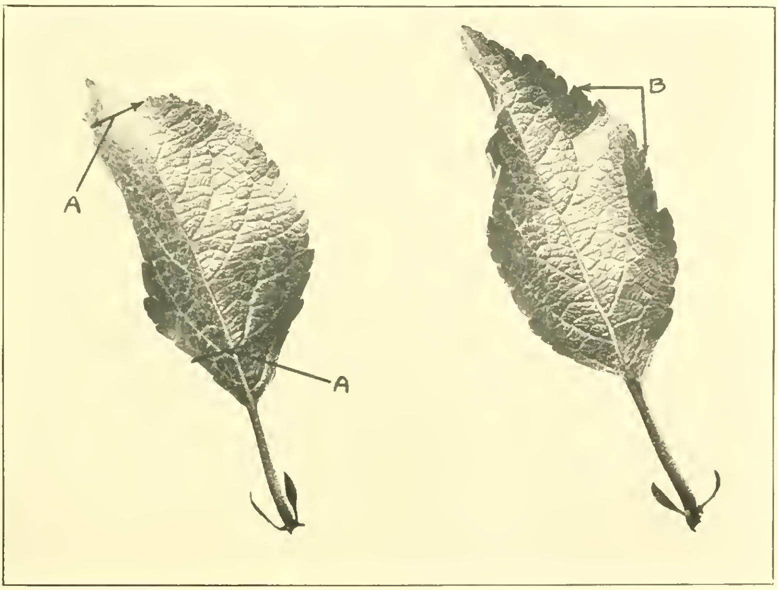

Photo by R. L. Coffin.

FIG. 17. — JONATHAN. Blade very small, more or less folded, sometimes reflexed, narrow at base and apex (A); serrations moderately sharp, coarse and irregular (B).

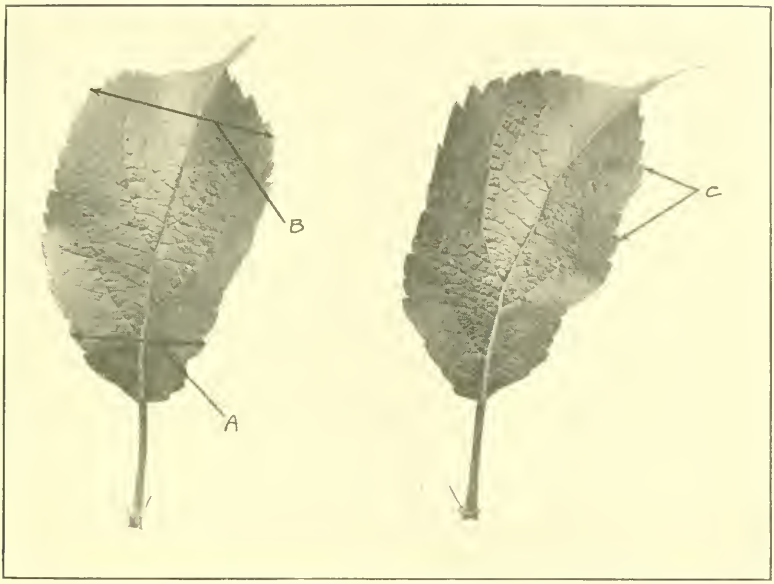

Photo by R. L. Coffin.

FIG. 18. — KING DAVID. Blade small, narrow at base (A), but broader at apex (B), more or less folded and reflexed; serrations moderately sharp, coarse and irregular (C).

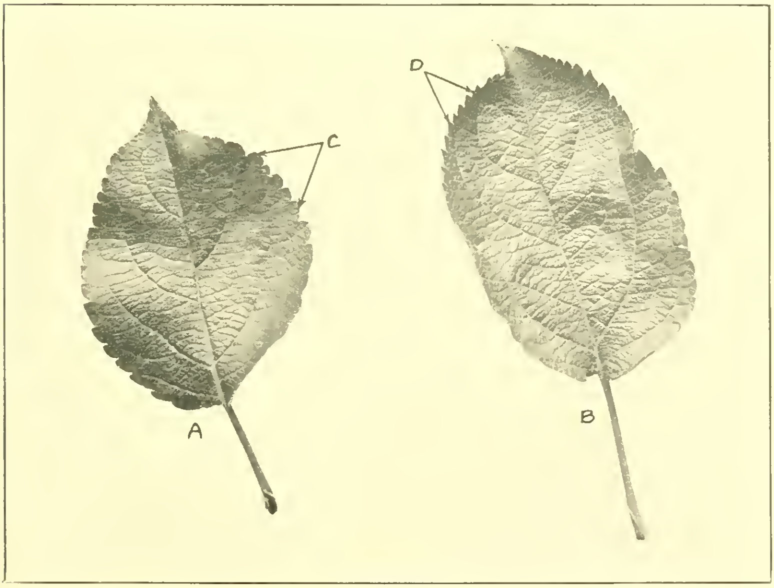

Photo by R. L. Coffin.

FIG. 19. — STAYMAN. Blade medium or below in size, usually nearly round (A), sometimes oblong (B); serrations usually dull and coarse (C), sometimes sharp (D). An exceptional variety, often having leaves of two distinct types.

Fig. 20. — Opalescent. Blade medium size, somewhat folded, sometimes slightly waved (A); serrations rather dull, fine and regular (B).

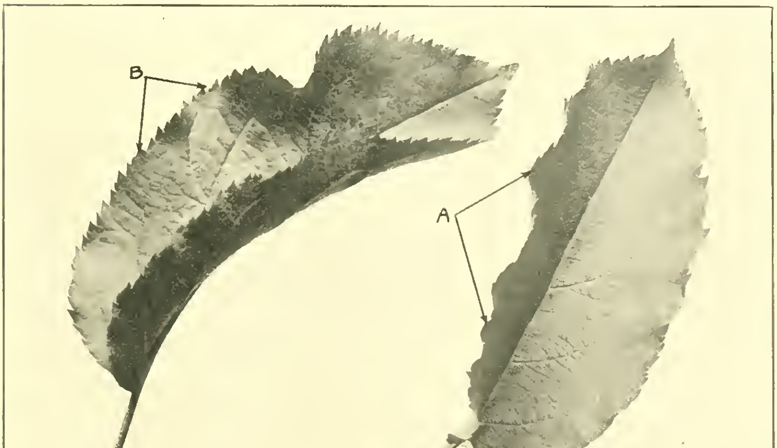

Photo by R. L. Coffin.

Fig. 21. — Fall Pippin. Blade large, long and rather narrow, folded, reflexed and waved or wrinkled (A); serrations sharp, coarse and distinct (B).

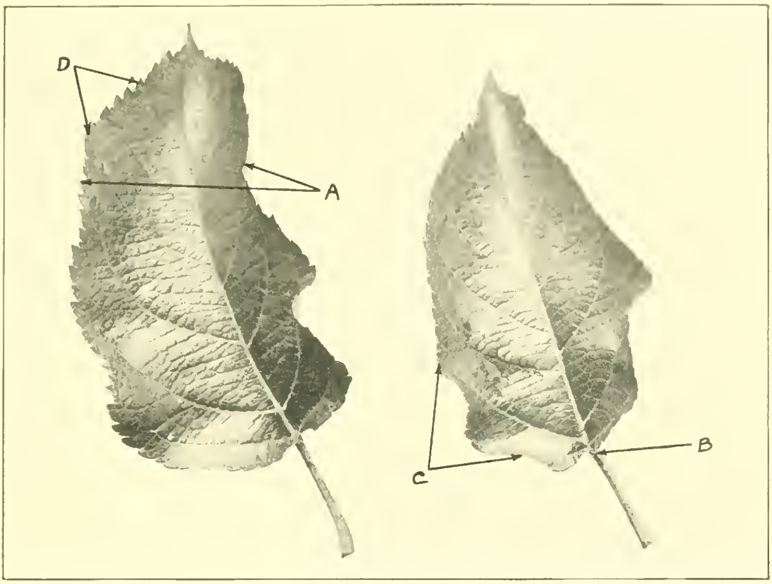

Photo by R. L. Coffin.

FIG. 22. — HUBBARDSTON. Blade medium size, folded (A), reflexed (B), and waved (C); serrations rather sharp and distinct, rather irregular (D).

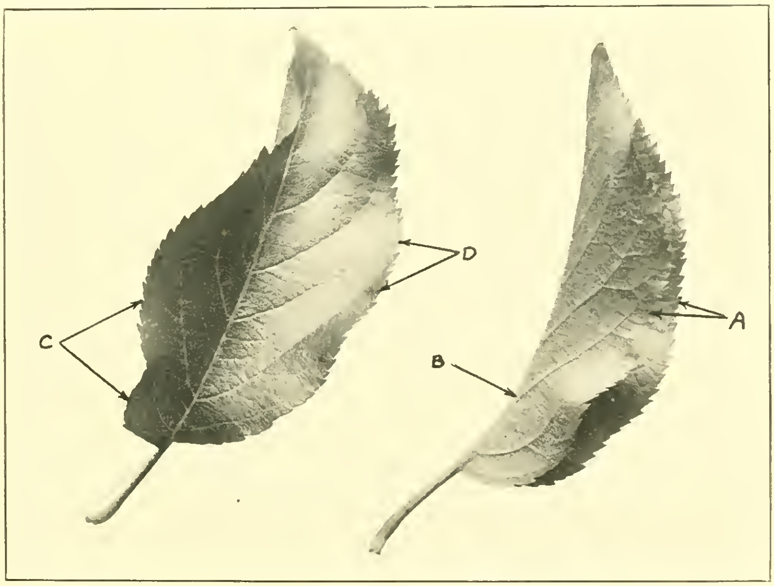

Photo by R. L. Coffin.

FIG. 23. — GRIMES. Blade medium size, folded (A), reflexed (B), and waved (C); serrations sharp, regular and distinct (D).

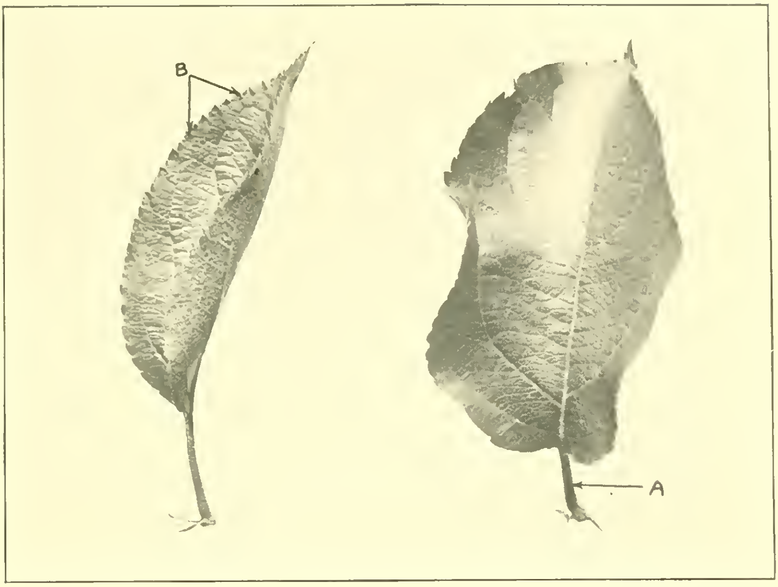

Photo by R. L. Coffin.

FIG. 24. — TOMPKINS KING. Petiole short (A); blade large, folded and reflexed, usually waved; serrations sharp, distinct and quite regular (B).

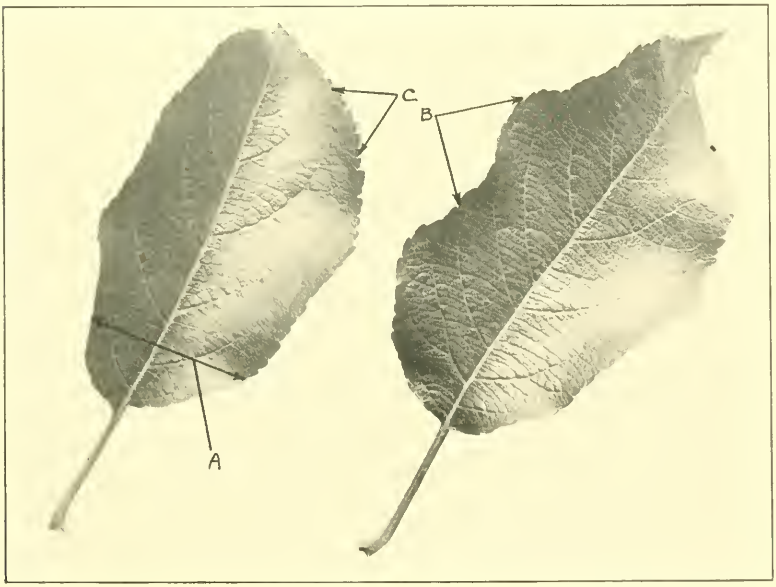

Photo by R. L. Coffin.

FIG. 25. — BEN DAVIS. Blade medium size or above, long and narrow especially at base (A), folded, reflexed and waved (B); serrations dull, rather fine and irregular (C).

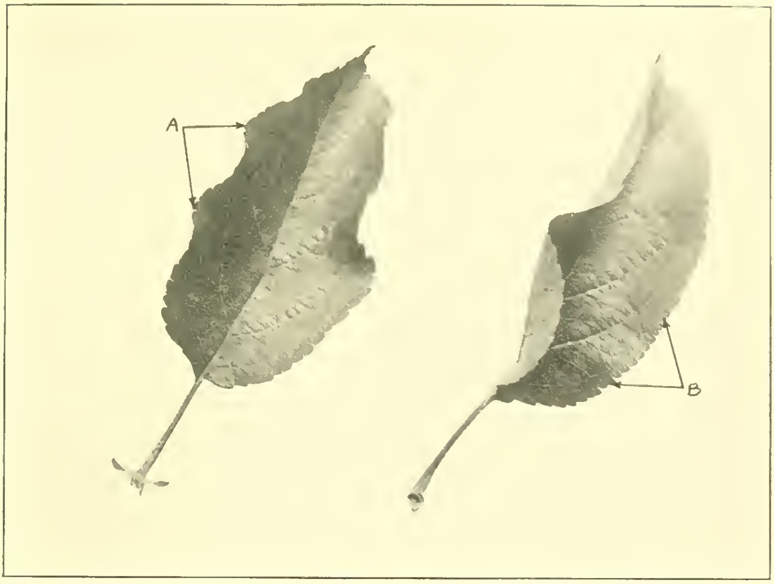

Photo by R. L. Coffin.

FIG. 26. — ESOPUS SPITZENBURG. Blade medium size, folded, reflexed and more or less waved (A); serrations rather dull and quite regular (B).

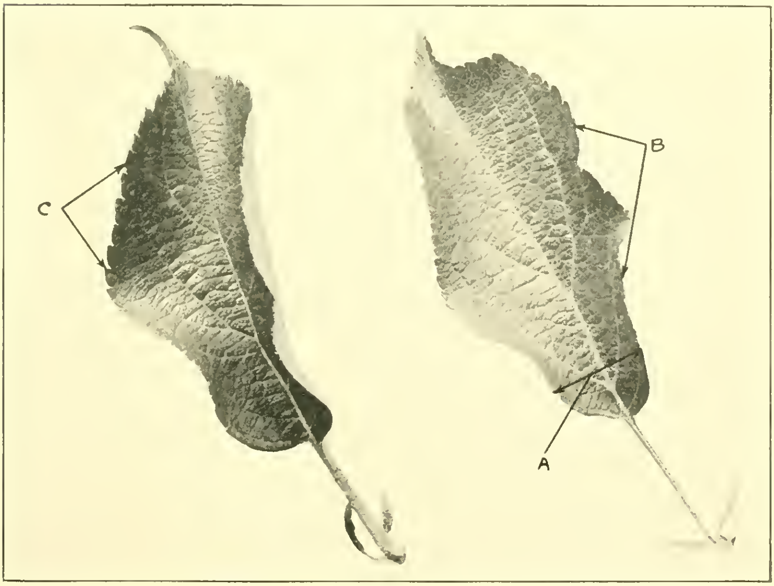

Photo by R. L. Coffin.

FIG. 27. — TOLMAN. Blade medium size, very narrow at base (A), narrow at apex, folded, reflexed and waved (B); serrations rather dull and coarse (C).

Description of Varieties.

There are many leaf characters that are of considerable value in identifying varieties that cannot be well shown in photographs. They have been discussed in the text. In order to present these characters the following technical descriptions of the leaf characters of the varieties illustrated are presented: —

Baldwin. — Petiole medium. Blade above medium size, folded near margin, straight or slightly reflexed, not waved, broad oval, broad at base and very broad at apex, nearly erect, rather thin, smooth, fine texture with little pubescence. Serrations sharp, strongly forward, medium size, fairly regular, usually curved, rather deep and close set. Color medium green. (Fig. 8.)

Ben Davis. — Petiole long, medium size. Blade below medium size, folded, often reflexed, waved, narrow oval, very narrow at base, nearly spreading, rather thin, smooth with considerable pubescence. Serratures dull, moderately forward, rather small and shallow, sometimes slightly curved, quite regular. Color slightly grayish green. (Fig. 25.)

Delicious. — Petiole length, short to medium. Blade below medium size, slightly folded, straight or slightly reflexed, even, ovate, apex narrowing into the point, rather erect, thick, rather coarse texture with little pubescence. Serratures moderately sharp, rather coarse and deep, irregular. Color deep green. (Fig. 14.)

Esopus Spitzenburg. — Petiole medium. Blade below medium in size, more or less folded and waved, slightly reflexed, oval or ovate usually narrowing at apex, medium in texture and pubescence. Serratures rather dull, small and rather shallow, fairly regular. Color medium green. (Fig. 26.)

Fall Pippin. — Petiole medium long, stout. Blade large, folded, reflexed and waved, ovate with apex merging into acute or acuminate point, rather smooth and shining. Serratures sharp, deep and distinct, not curved, rather irregular. Color bright clear green. (Fig. 21.)

Gravenstein. — Petiole medium. Blade large, flat, not waved, oval, smooth and shining. Serratures rather sharp, shallow, fairly regular. Color medium green. (Fig. 2.)

Grimes. — Petiole medium. Blade medium size, strongly folded, waved and reflexed, long and narrow, narrowing at base and apex, rather thin, smooth and shining, with little pubescence. Serrations sharp, distinct and rather deep, rather irregular. Color medium green. Grimes resembles Wagener, but it has less pubescence, is thinner, and has finer and sharper serrations. (Fig. 23.)

Hubbardston. — Petiole rather short, medium size. Blade below medium, folded, more or less waved, reflexed, generally ovate, rounded at base and generally narrow at apex, nearly erect, medium thickness, dull, rather coarse texture with considerable pubescence. Serratures fairly sharp, medium size, moderately deep and distinct, fairly regular. Color deep grayish green. (Fig. 22.)

Jonathan. — Petiole short and rather slender. Blade very small, more or less folded, waved, sometimes reflexed, oval, narrow at base and apex, rather spreading, rather coarse texture with considerable pubescence. Serratures rather dull, rather coarse, shallow and irregular. Color grayish green. (Fig. 17.)

King David. — This is like Jonathan, except that the leaf is somewhat larger, distinctly broader in the apex, less apt to be folded and with somewhat less pubescence. (Fig. 18.)

McIntosh. — Petiole short and rather stout. Blade large, flat or slightly folded near margin, straight, not waved, broad oval, often cordate at base, spreading, rather coarse and thick, with considerable pubescence. Serratures dull, medium size, very shallow at base, fairly regular. Color deep grayish blue green. (Fig. 3.)

Northern Spy. — Petiole generally rather long and slender. Blade medium size, more or less folded and waved, often slightly reflexed, ovate, erect, rather thin, smooth with little fine pubescence. Serratures rather sharp, medium size, rather shallow, fairly regular. Color clear medium green. (Fig. 16.)

Oldenburg. — Petiole long. Blade above medium to large, more or less folded, slightly reflexed, distinctly waved, broad oval, broad at base and apex, spreading, medium thickness, rather dull surface with medium pubescence. Serratures rather dull, medium in size and depth, irregular. Color medium green. (Fig. 6.)

Opalescent. — Petiole medium. Blade medium size, somewhat folded, sometimes waved, oval, rather narrow at base, apex narrowing into the point, spreading, medium thickness, smooth and shining with little pubescence. Serratures dull, rather small, of medium depth, quite regular. Color medium green. (Fig. 20.)

Red Astrachan. — Petiole medium. Blade large, flat or slightly folded, waved or wrinkled, broad oval, broad at apex, spreading, medium thickness, dull surface with a little pubescence. Serratures dull, medium in size and depth, rather irregular. Color dull medium green. (Fig. 5.)

Rhode Island Greening. — Petiole long, medium size. Blade large, flat or reverse curved, not waved, broad oval, rounded or narrow at base, broad at apex, spreading or drooping, smooth with little pubescence. Serratures very sharp and distinct, rather deep, fairly regular. Color deep clear green. (Fig. 4.)

Roxbury Russet. — Petiole medium or short, rather stout. Blade medium in size, folded near edge, not waved nor reflexed, broad oval, broad at base and apex, spreading, rather smooth with medium pubescence. Serratures only moderately sharp, rather small, not deep, rather irregular. Color deep green. Much like Baldwin, but the serratures are not so sharp nor so close set and are not curved. (Fig. 9.)

Stayman. — Petiole short to medium. Blade rather small, roundish or broad oval, partly folded, not waved nor reflexed, spreading, rather thick, coarse texture with medium pubescence. Serratures dull and coarse to sharp and small. Color deep green. Stayman seems to be unique in having distinct types of leaves as shown in Fig. 19.

Tolman. — Petiole medium. Blade medium, folded, reflexed and waved, narrow oval, narrow at base and apex, spreading, medium texture with considerable pubescence. Serratures moderately sharp, medium size, quite distinct, generally quite regular. Color deep bluish or grayish green. (Fig. 27.)

Tompkins King. — Petiole rather short and stout. Blade medium to large, folded, more or less waved and reflexed, rather long oval, rather narrow at base and apex, spreading, medium thickness with little pubescence. Serratures sharp, medium to small, shallow and close set. Color medium green. (Fig. 24.)

Wagener. — Petiole, medium or short, stout. Blade medium or above, strongly folded and reflexed, more or less waved, oval with medium base and apex, erect, rather thin with moderate pubescence. Serratures quite sharp, rather coarse, deep and distinct, not curved. Color medium green or slightly grayish. Wagener resembles Grimes, but the leaf is coarser, the serrations not quite so sharp, and it has more pubescence. (Fig. 15.)

Wealthy. — Petiole medium or rather long, slender. Blade medium or above, nearly flat, often somewhat reflexed, often spiral and waved, oval with narrow base and apex, spreading, thick and with little pubescence. Serrations dull, medium in size and depth, somewhat irregular. Color medium green. Wealthy resembles Oldenburg, but the serrations are duller, the blade less folded and much narrower at the base and apex. (Fig. 7.)

Williams. — Petiole medium, rather slender. Blade medium size, partly folded, somewhat reflexed, sometimes coarsely waved, spreading, rather coarse with little pubescence. Serratures dull, small and shallow, regular. Color medium green. (Fig. 11.)

Winter Banana. — Petiole short and stout. Blade medium size, folded near margin, midrib bent at base, not often waved, narrow oval, spreading, medium thickness with little pubescence. Serrations rather dull and shallow, pointing well forward. Color rather pale green. (Fig. 10.)

Wolf River. — Petiole medium. Blade flat or somewhat folded, often waved and wrinkled, often reflexed, oval, narrow at base and apex, spreading, medium thickness, rather coarse with medium pubescence. Serratures very dull, quite distinct and rather irregular, often double. Color medium green. (Fig. 12.)

Yellow Transparent. — Petiole medium. Blade medium size, more or less folded, often waved and somewhat reflexed, often spiral especially near tips of shoots, rather narrow oval, rather narrow at apex, smooth, rather fine texture with considerable pubescence. Serratures dull, rather small and shallow, quite regular. Color rather paie green. (Fig. 13.)

Glossary.

In the foregoing descriptions there are a number of words that are used in a restricted, technical sense. Definitions of the technical meaning of these words are here given: —

Acute: sharp pointed.
Acuminate: very sharp pointed.
Apex: about one-third of the leaf blade. (See Fig. 1.)
Base: same as apex, but referring to the opposite end.
Blade: the leaf, barring petiole and stipules. (See Fig. 1.)
Cordate: heart-shaped; applied to shape of leaf base. (See McIntosh, Fig. 3.)
Close set: referring to serratures having little space between. (See Baldwin, Fig. 8.)
Curved: applied to "teeth" of serratures. (See Baldwin, Fig. 8.)
Distinct: having spaces between the "teeth" of serratures, the opposite of close set. (See Fall Pippin, Fig. 21.)
Drooping: applied to the angle of leaf and the shoot from which it grows; a very wide angle.
Erect: the opposite of drooping; a sharp angle between leaf and shoot.
Folded: the halves of the leaf curved upward toward each other.
Irregular: serratures of varying sizes.
Midrib: the main vein along the middle of the blade.
Point: the extreme tip of the leaf blade.
Pubescence: the short hairy growth found mainly on the under side of the leaf blade.
Reflexed: having the blade curved backward or downward.
Regular: serratures all of equal size.
Reverse curved: the midrib and blade bent slightly like the letter S.
Serratures, serrations: the notches on the margin of the leaf blade.
Spreading: the usual angle of the leaf and shoot; between erect and drooping.
Spiral: a slight twisting of the leaf blade. (See Wealthy, Fig. 17.)
Texture: applied to the surface of the leaf blade, due mainly to character of the net veins.
Waved: having undulating leaf margins.
Wrinkled: the same as waved, but with smaller undulations.

BULLETIN No. 209.

DEPARTMENT OF POMOLOGY.

EXPERIMENTS IN SOIL MANAGEMENT AND FERTILIZATION OF ORCHARDS.

BY J. K. SHAW.

THE OLD STATION ORCHARD.[1]

The orchard experiment here reported was begun in 1890 and has continued to the present time. It is, so far as the writer's knowledge goes, the oldest orchard fertilizer experiment in America, and perhaps in the world. The arrangement of the orchard is shown on page 34. It lies on a gentle western slope and is bordered on the west and north by grassland. To the east and south the slope is steeper and covered by a heavy growth of forest trees. The orchard and forest are separated by an open space which in the writer's judgment is sufficient to prevent any injurious influence on the orchard trees from root trespass, though there may possibly have been an injurious effect from shading. This, however, is distributed quite evenly over the whole orchard.

The soil is a strong and retentive gravelly loam underlain by a fairly compact subsoil. It is well supplied with moisture. A ditch above the orchard prevents surface wash from the forest slope above. It was originally somewhat overmoist, especially on plot 3, which is slightly lower than plots 4 and 5. This may have influenced in some degree the growth and yield of this plot, but in the writer's judgment any such influence is small even if it exists at all. Before the trees were planted tile drains were laid to care for surplus water.

[1] This experiment was planned and started by the late Dr. C. A. Goessmann as director and chemist of the State Experiment Station. For most of its life it has been under the direction of Dr. Wm. P. Brooks. The details of management and recording of data have been in the hands of several different men, recently of E. F. Gaskill and R. L. Coffin. The writer is responsible for the tabulation and interpretation of the data.

Below is shown the arrangement of the plots and trees. The trees are spaced 40 × 30 feet, with an additional space of 14 feet between plots. Plot 1 is at the north end of the orchard.

PLOT 1. — MANURE, 10 TONS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein (died before 1907).	Gravenstein.	Gravenstein (died in 1919).

PLOT 2. — ASHES, 2,000 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet (died in 1919).
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 3. — NO FERTILIZER.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin (died about 1913).	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 4. — BONE, 600 POUNDS; MURIATE OF POTASH, 200 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet (died in 1907–08).	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

PLOT 5. — BONE, 600 POUNDS; LOW-GRADE SULFATE OF POTASH, 400 POUNDS.

Rhode Island Greening.	Rhode Island Greening.	Rhode Island Greening.
Roxbury Russet.	Roxbury Russet.	Roxbury Russet.
Baldwin.	Baldwin.	Baldwin.
Gravenstein.	Gravenstein.	Gravenstein.

Fertilizer Treatment.

Previous to 1889 the soil was in rather poor condition, but had been gradually improved by cultivation in corn and other cereals and grass. The manurial treatment was begun in the spring of 1889, and the following annual applications were continued up to and including 1916. Since 1916 no manure or fertilizer has been applied.

Plot.	Fertilizer.	Pounds per Acre.
1	Barnyard manure	20,000
2	Ashes	2,000
3	Check, no fertilizer	
4	Ground bone	600
	Muriate of potash	200
5	Ground bone	600
	Low-grade sulfate of potash	400

The fertilizer and manure have been applied on various dates, generally between April 1 and May 15, though in 1906 they were not applied until July 2.

Soil Management.

During the period from 1889 to 1893 various crops, such as barley, oats, corn, vetch and soy beans, were grown in the orchard. In the fall of 1893 it was seeded to rye and grass, and the sod then established continued until the fall of 1910. For the first few years small circles around the trees were kept free from grass by hand culture. Until 1902 the grass was cut usually twice each year, made into hay and removed from the orchard. In that year the first crop was made into hay and the second allowed to lie in the orchard. Since 1902 no hay has been removed, but the grass has been cut and allowed to lie where it fell. In November, 1910, four strips, each about 8 to 12 feet wide, were plowed the long way of the orchard. These strips have since been kept in cultivation by harrowing four to eight times during the summer; and usually about August 25 a cover crop of oats or rye has been sown. The grass along the tree rows has been cut and allowed to lie as before.

The history of the soil management, therefore, falls into four periods: —

1. With various intercrops . . . . 1889–1893, 5 years.
2. In sod with grass removed . . . . 1894–1902, 9 years.
3. In sod mulch . . . . 1903–1910, 8 years.
4. In strip cultivation . . . . 1911–1920, 10 years.

The fourth period might be subdivided between 1916 and 1917, marking the cessation of the application of fertilizer and manure.

Orchard Management.

The trees have been pruned in most years, at least since they have been in bearing. Heading back the new growth has been practiced more or less, and all dead wood has been removed.

During the early years apparently no spray treatment was given. Beginning in 1902 annual treatments for San José scale have been given which have kept the pest from doing serious damage to the trees. Generally lime-sulfur has been used for scale control, but in 1912 and 1913 miscible oil was applied in the late fall. This was followed by the dying of branches on some trees, which was attributed in part to the use of the oil, so that it was discontinued. One or two summer sprays have been given except in a very few years when the crop promised to be very light. Curculio injury has been common in most years, and in 1913 the red bug was found to be present. Partial control of these pests has been secured by the use of nicotine preparations in the spray. During the early years copper sulfate preparations and Paris green, and recently lime-sulfur and arsenate of lead, have been used in the summer sprays.

No records of growth were taken previous to 1902. Beginning in that year the circumference of the trunk 6 inches from the ground has been measured annually except in the years 1905, 1906, 1910, 1912 and 1918. Records of the yields of drops and picked fruit for each variety from each plot have been taken each year. The yield of individual trees has not been taken.

Five trees have died since the orchard came into bearing. One Gravenstein in plot 1 died before 1907, and another in 1919. The remaining Gravenstein in this plot was girdled by mice in 1907–08, but was bridge grafted and is now in good condition. One Baldwin in plot 3 died about 1913, one Roxbury Russet in plot 4 died in 1907–08, and one in plot 2 in 1919. (See page 34.) These have all been replaced, but none of the young trees is in bearing. In the tables given for trunk circumference the missing trees are omitted from the averages, but no corrections are made in yields.

Growth Records.

The only record of tree growth is that of trunk circumference which has been taken in most years beginning in 1902. Fig. 1 shows the averages of these measurements by plots. It may fairly be assumed that at the start the trees on the several plots averaged the same size. The differences in 1902 show what happened under the system of sod with removal of the hay. The manure and sulfate plots were alike, averaging about 27 inches. The graph shows that these two plots have steadily diverged up to the present time.

Certain years, such as 1904 and 1908, seem to have been especially favorable to tree growth, while 1917 was unfavorable. The writer has tried to correlate these variations in growth with rainfall, temperature, sunshine and size of crop, but without very much success. It is evident that no one of these factors is entirely responsible.

The relative growth on the different plots is more clearly shown in Fig. 2, where the average trunk circumference of the trees on plot 1 is shown as 100, and that of the other plots as percentages of plot 1. The steady decline of plot 5 from 100 to 89 per cent is clearly shown. Plot 2 (wood ashes) had fallen to about 88 per cent in 1902, and continued to fall off slowly until about 1912, but since that time it has nearly held its own. Plot 4 (bone and muriate) has behaved about the same as plot 2.

The check plot (plot 3) had fallen below 80 per cent at the commencement of our records, and continued to fall off rapidly up to 1911. From 1911 to 1915 it not only kept up with plot 1, but actually gained quite rapidly. Since 1915 it has kept even with plot 1 until the season of 1920, when plot 1 made remarkably strong growth, causing a relative falling off of plot 3 and of the other three plots as well.

The relative gain of plot 3 is beyond doubt due to cultivation of strips between the tree rows begun in the fall of 1910. As shown in Fig. 1, cultivation does not seem to have increased the growth on plot 1, but its effect is seen in all the other plots, though most strikingly in plot 3.

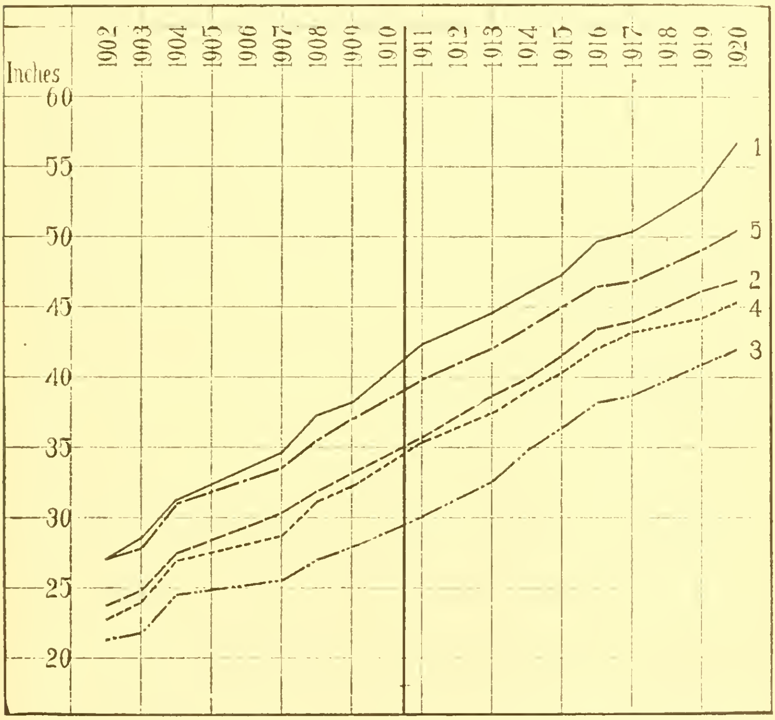

Fig. 1. — Increase in trunk circumferences. The perpendicular line marks the transition from sod mulch to strip cultivation. Plot numbers are shown at the right. See page 35 for treatments given.

No fertilizers of any kind have been applied since 1916, yet the growth on plot 1 has been well maintained as shown in Fig. 1. The other plots show a decrease in rate of growth since 1915, as shown in Fig. 2. It seems doubtful if this can be ascribed wholly to the cessation of fertilizer applications, because the decrease appears first in 1916, when fertilizers were applied, and it is seen in plot 3 which has never had any fertilizer applications. It seems more reasonable to suppose that the relative gain on plots 2, 3, 4 and 5 since 1911 was due mostly to the stimulus of cultivation which lasted through 1915. From 1915 to 1919 the check plot maintained just about the same growth as plot 1, while plots 2, 4 and 5 fell away. This may indicate an effect of the withdrawal of the fertilizer applications, though, as stated above, the fact that it is seen in 1916 indicates that it is not wholly due to that cause.

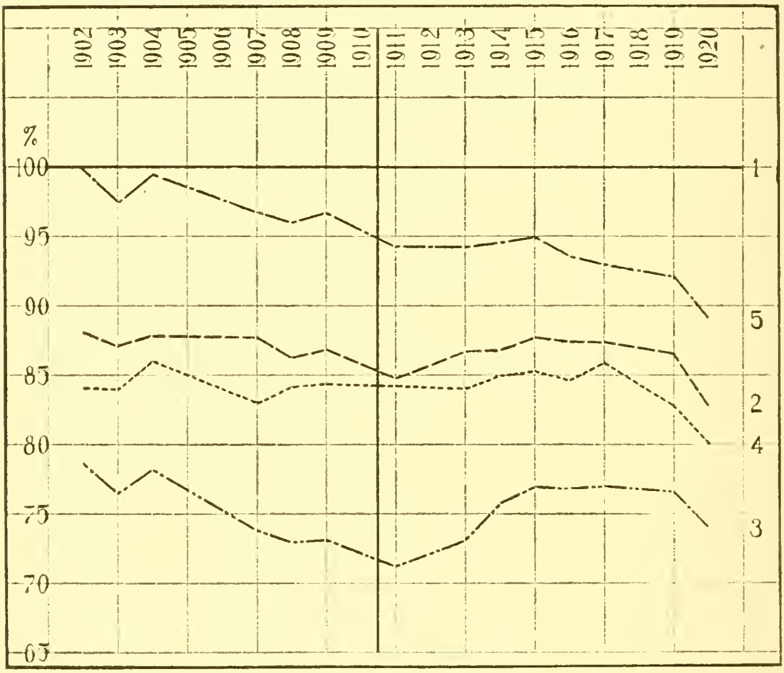

FIG. 2. - Relative trunk circumferences. Circumferences on plot 1 taken as 100 per cent. Plot numbers are shown at the right.

Varietal Response to Treatment.

Turning now to the question of whether all varieties have responded in the same manner to the various fertilizer treatments, we may examine Fig. 3. This shows the average trunk circumferences of the four varieties at three periods: first, in 1902, at the end of the period of hay removal; second, in 1911, at the end of the sod mulch period; third, in 1919, after nine years of partial or strip cultivation.

An examination of these graphs shows that the several varieties have maintained about the same relative positions during the entire period for which growth records have been kept. With increased size of the trees, the absolute differences have naturally increased. Rhode Island Greening has done better on the manure and ashes plots than on the other three

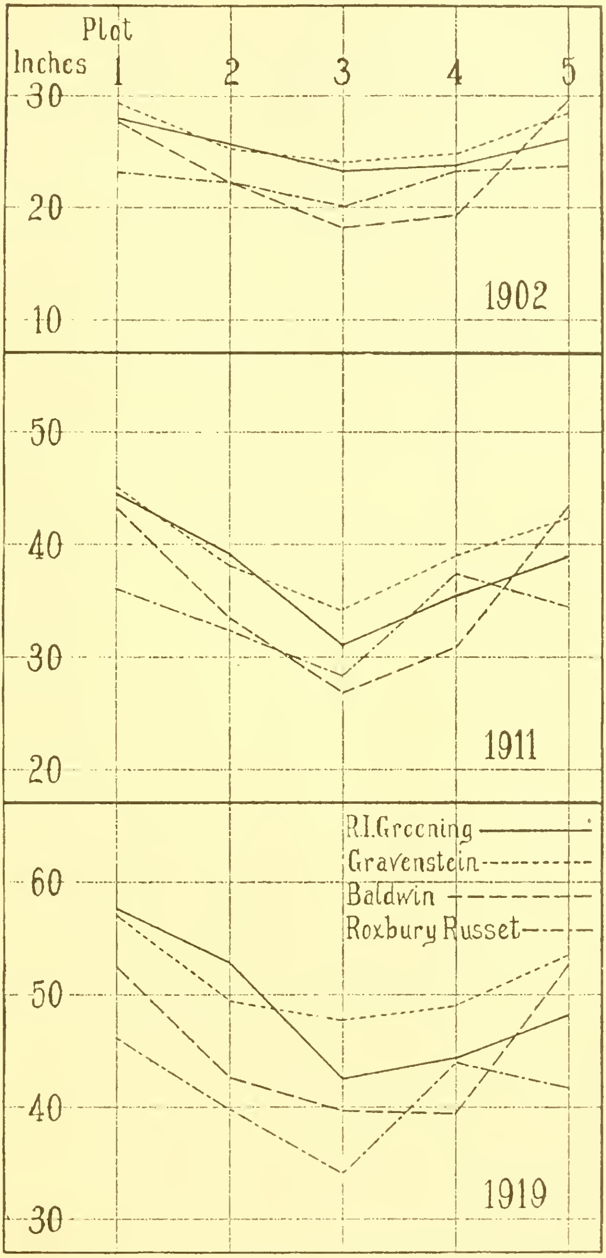

FIG. 3. — Trunk circumferences by varieties. Figures across top are plot numbers.

plots. Roxbury Russet is larger than Baldwin on the muriate plot, and the opposite is true on the sulfate plot, the differences here being quite marked and increasing with the age of the trees.

On the manure plot Rhode Island Greening has gained on the other varieties, which may be due to the fact that it is the outside row with free exposure to the north. On the ashes plot no relative change of the four varieties appears. On the check plot Baldwin has gone ahead of Roxbury Russet during the period of strip cultivation. Gravenstein has increased its lead over the other varieties, especially during strip cultivation. On the sulfate plot Gravenstein has gone ahead of Baldwin during the strip cultivation period, while the other varieties have maintained very much the same relative positions.

While there seem to be some quite marked varietal differences in growth, notably in the Baldwin and Russet on the two potash plots, it would be unsafe to conclude that they are due to the fertilizer treatments. They may be in part, but it is more likely that disease, natural soil differences, or inherent differences in the stocks used may be responsible.

Yield Records.

In Table 1 are given the total yields by plots and by varieties for the periods when no cultivation was practiced, and for the later period of strip cultivation.

TABLE 1. — *Total Yields by Varieties and by Plots (Pounds).*

Varieties.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
R. I. Greening:						
Before 1912	11,043	5,420	1,471	5,062	5,091	28,087
1912–20	16,989	14,310	7,344	10,367	9,881	58,891
Totals	28,032	19,730	8,815	15,429	14,972	86,978
Roxbury Russet:						
Before 1912	7,832	4,930	1,652	6,010	7,375	27,799
1912–20	12,123	7,620[1]	4,554	6,954[2]	8,397	39,648
Totals	19,955	12,550	6,206	12,964	15,772	67,447
Baldwin:						
Before 1912	8,168	4,155	735	2,359	10,936	26,353
1912–20	12,853	10,225	3,515[3]	5,234	12,616	44,443
Totals	21,021	14,380	4,250	7,593	23,552	70,796
Gravenstein:						
Before 1912	4,308	2,697	1,490	4,412	4,035	16,942
1912–20	3,839[4]	5,855	5,289	7,175	5,175	27,333
Totals	8,147	8,552	6,779	11,587	9,210	44,275
All varieties:						
Before 1912	31,351	17,202	5,348	17,843	27,437	99,181
1912–20	45,804	38,010	20,702	29,730	36,069	170,315
Totals	77,155	55,212	26,050	47,573	63,506	269,496

[1] One tree died in 1919.
[2] One tree died in 1907.
[3] One tree died in 1913.
[4] One tree died before 1907, and one in 1919.

The yields have been light, averaging only about $2\frac{1}{4}$ barrels per year per tree for the period from 1912 to 1920, inclusive, when the trees were practically mature. Rhode Island Greening has been the heaviest producer, deriving its superiority largely from plots 1 and 2. Baldwin is second, due in part to its superiority on plot 5. Roxbury Russet is third, and Gravenstein fourth, this variety being considerably inferior to the others in yield.

In total yields of all varieties by plots, the order is the same as for the size of the trees measured by trunk circumference. Plot 1 is ahead, followed by plots 5, 2, 4 and 3 in order.

All varieties increased their yield strikingly in the second period on nearly all plots, and especially on plot 3, the unfertilized plot. Here the total yield of all varieties was nearly fourfold. Baldwin increased nearly fivefold despite the loss of one of the three trees in 1913. On plot 1 the increase of all varieties was a little less than 50 per cent, though the yield of Gravenstein fell off, owing to the death of one tree before 1907, and the decline and death of another in 1919. If we assume that the normal increase due to growth of the trees is about 50 per cent, then plot 3 has increased its yield about two and one-half times over its normal, while the increase on plot 2 was about 40 per cent more than this assumed normal increase. Plot 4 has increased slightly more than the normal, while plot 5 has failed to make the normal gain.

There are several suggestive things that can be noted concerning the response of the different varieties to strip cultivation, but the small number of trees involved makes it rather doubtful if these differences have real significance.

The total yield of apples from the five plots from 1902 to 1920, inclusive, is shown graphically in Fig. 4. The heavy crops have been in the odd years, and are shown by heavy lines, while the light yields of the even years are shown by the lighter lines. The heavy perpendicular line between 1910 and 1911 marks the transition from sod mulch to strip cultivation.

This chart shows that in the off years there were no very great nor consistent differences between the plots until the 1920 crop. Nor has there been a very great increase in yield with the larger size of the trees in succeeding years. The off-year crop on the unfertilized plot has been the lowest of all in most years until the last two crops, when it has been about the average of the whole orchard. This better showing probably is the result of the increased growth of these trees since strip cultivation has been practiced. The crop of 1920 was heavier than that in any other off year, and, together with the light crop set in 1921 at the time of this writing, may mark a reversal of the off and on years. In 1920 the crops on the several plots were in much the same order as in the on years.

The off-year yields of the muriate and sulfate plots have been closely parallel, and the same is true of the on-year yields, yet the yields of the muriate plot have been distinctly inferior to those of the sulfate plot. This difference is less since 1911 than before, and may be due merely to the smaller size of the trees. The manure plot has been the best producer in most years, and its superiority seems to have increased in the last three on-year crops. The ashes plot has approached the manure plot more closely since 1911 than before. The unfertilized plot has been, up to 1920, far in the rear of all the fertilized plots, though showing material gains in on-year yields since 1911, which brought it slightly above the muriate plot in 1919.

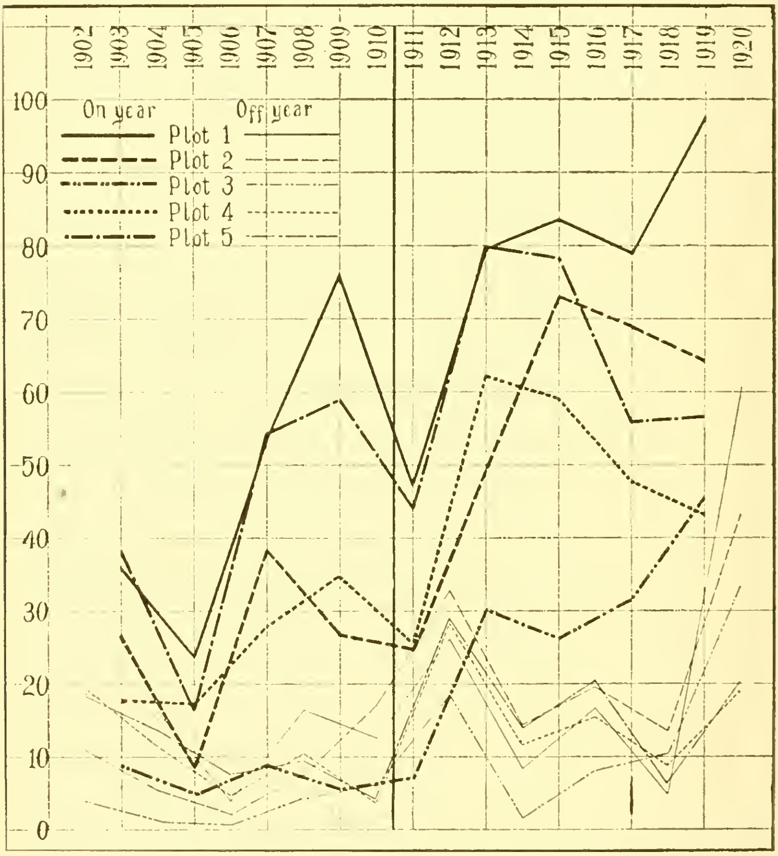

FIG. 4. — Total yields by plots in hundreds of pounds. The odd numbered years are the bearing or "on" years. Figures at left are hundreds of pounds.

It is apparent that the effect of the manurial treatment on yield has been slight in the off years, but in the on years it seems reasonable to conclude that there have been differences in yield due to the different manurial treatments. These differences in the on years follow closely the differences in growth of the trees. It is probable that the fertilized plots have exceeded in yields the unfertilized plot mostly because the trees were larger. The fertilized plots have received greater or less supply of nitrogen.

Many experiments have shown that abundant nitrogen favors the set of fruit. There is also no doubt that on these plots the fruit has been larger than on the unfertilized plot. These additional factors would contribute to the increased yield of the trees on the four fertilized plots. Inasmuch as the trees on the unfertilized plot now approach those of the other plots in size, it is probable that this inferiority would be somewhat less marked in the future were the treatment to be continued as in the past.

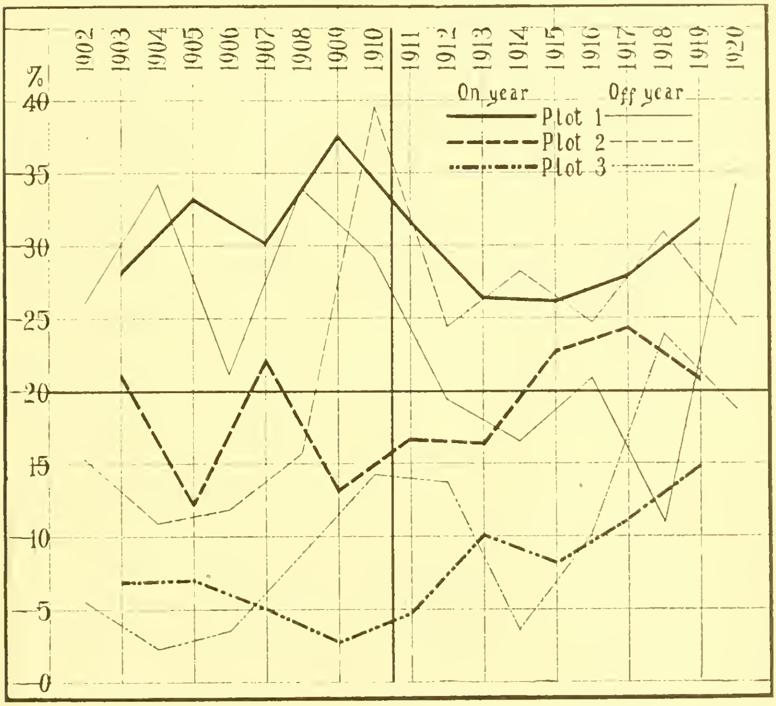

FIG. 5. — Yields by plots in percentages of total yields of the whole orchard. Plots 1, 2 and 3.

It was observed that the ashes, muriate and sulfate plots produced considerable growth of clover while fertilizer applications were kept up. When these ceased in 1916 the clover gradually disappeared. No doubt this growth of clover contributed nitrogen to the trees. The decline in growth and production of these three plots during the last four or five years may have been in some measure due to this lessened nitrogen supply.

The relative yields of the five plots are shown from another viewpoint in Figs. 5 and 6, where the yields are shown in percentages of the total crop of the whole orchard. Fig. 5 shows plots 1, 2 and 3, and Fig. 6 shows plots 4 and 5. Here, again, the heavy lines show the on-year yields and the light lines the off-year yields. Inasmuch as there are five plots, the horizontal line along the abscissa of 20 per cent shows what we may call the normal yield of each plot.

The manure plot produced from 8 to 17 per cent excess over its normal 20 per cent under sod mulch in the on years, and only a little smaller excess in the off years. Under strip cultivation since 1910 it has fallen to an average excess of about 8 per cent in the on years, and in three of the off years it has failed to produce its normal 20 per cent of the crop. Of course this percentage loss of the manure plot is made up by the other plots, and the ashes plot has helped do this. In all but two of the on years under sod mulch it failed to produce its normal 20 per cent, while in three out of five crops under strip cultivation it has exceeded its normal share. In the off years since strip cultivation its excess is much more marked. The unfertilized plot was far behind under the sod mulch system, but shows fairly consistent gains since strip cultivation has been practiced, and in one of the off years has exceeded its normal 20 per cent.

Effect of Form of Potash. — The muriate and sulfate plots have usually been in close accord in the off years, but in the on years there was marked superiority in the sulfate plot up to and including 1911, with the exception of 1905. Since 1911 the yields of these two plots have not differed widely.

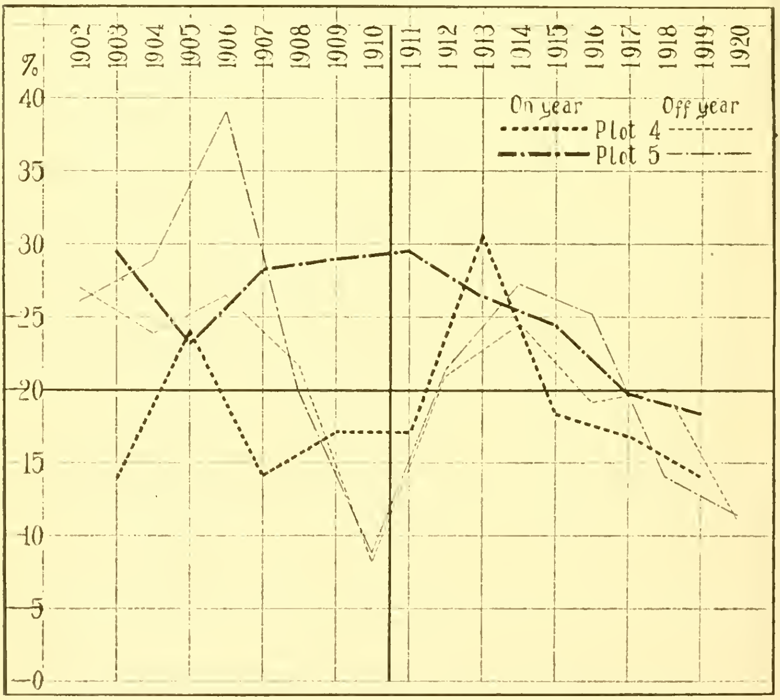

FIG. 6. — Yields by plots in percentages of total yields of the whole orchard. Plots 4 and 5.

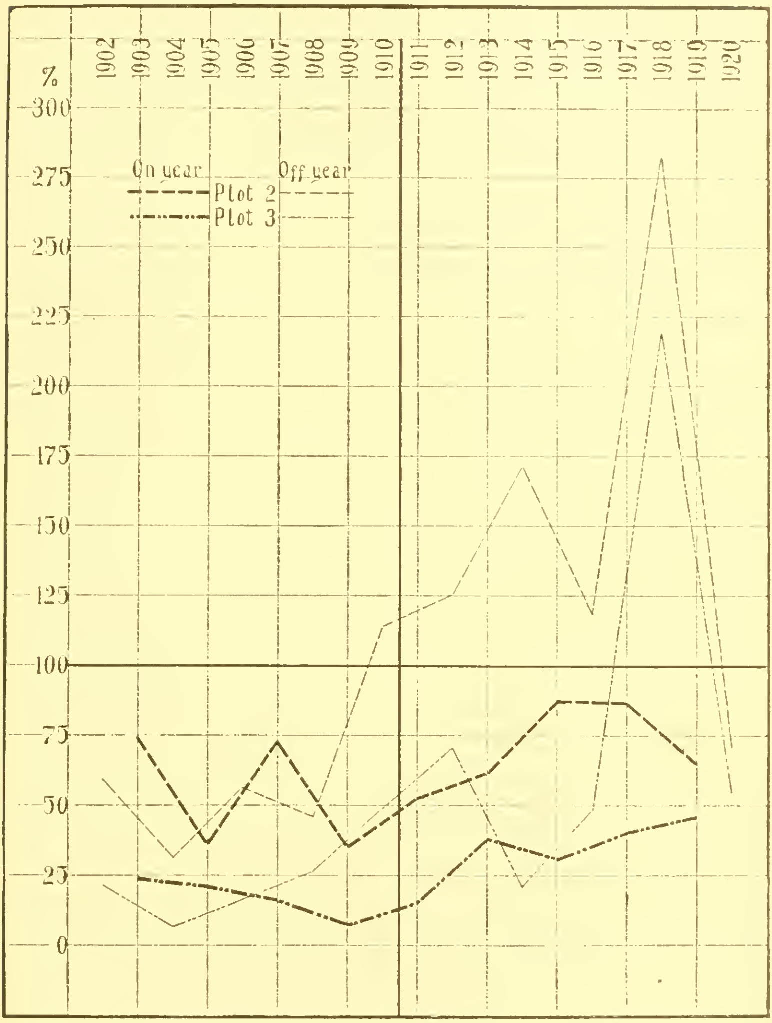

FIG. 7. — Relative yields of plots 1, 2 and 3. Yields on plot 1 taken as 100 per cent.

Whether the wide differences of the crops of 1903, 1907, 1909 and 1911 were accidental, or were due to the different fertilizers used on the sod mulch system then practiced, it is impossible to say. It seems certain that no significant differences have appeared since 1911, and of course the buds for that crop were formed while the plots were handled under the sod mulch system. Both these plots have, since 1913, produced a steadily decreasing proportion of the crop of the orchard.

Still another view of the plot yields is shown in Figs. 7 and 8, which show the yields of plots 2, 3, 4 and 5, with plot 1, the manure plot, taken as 100. These figures show clearly how plot 1 has often been exceeded by the other plots in the off years and scarcely at all in the on years. The increased production of the ashes and unfertilized plots since strip cultivation was begun is shown. The relative decrease of the ashes and unfertilized plots under sod mulch is shown, and also their gain on the manure plot when strip cultivation was begun. The unfertilized plot still continues a relative increase, while the ashes plot shows a falling away in the last few years. Fig. 8 shows clearly the parallel courses of the muriate and sulfate plots, with a relatively wider difference under sod mulch, and a gradual convergence since strip cultivation has been practiced.

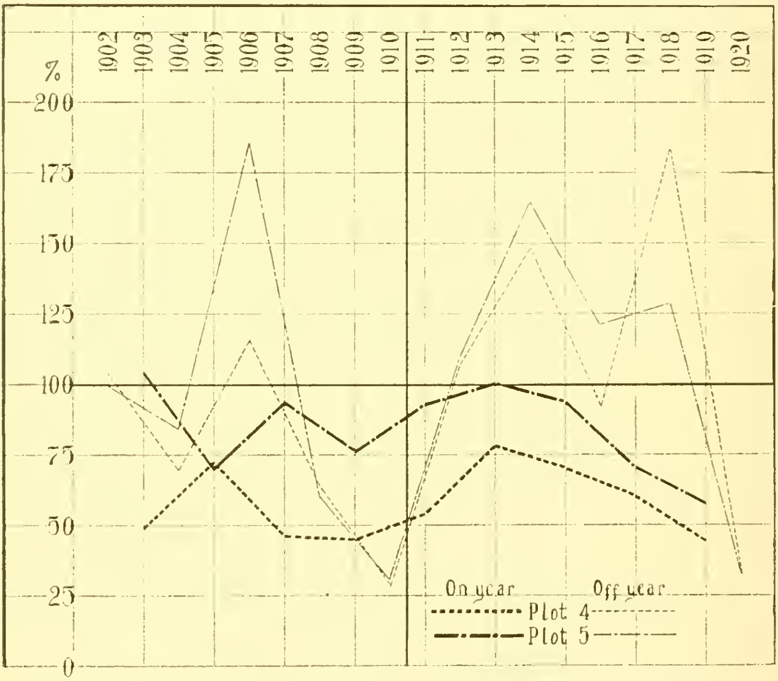

FIG. 8. — Relative yields of plots 1, 4 and 5. Yields on plot 1 taken as 100 per cent.

Correlation between Growth and Yields.

It is interesting to compare these graphs with Fig. 2 showing similar measures of growth as indicated by trunk circumference. Several investigators have shown a close correlation between growth and fruit production. Within limits the two go together, — the more growth the greater fruit production. This conclusion is supported by a comparison of Fig. 2 with Figs. 7 and 8. Especially do the lines representing growth and production on the unfertilized plot show a general resemblance, both falling off under sod mulch and rising when strip cultivation was begun. There is only a little less striking resemblance in the curves for the other three plots.

Quality.

Considerable differences in quality of the product of the several plots have appeared. This is considered to include size, color, keeping quality and dessert quality. No special records of size have been kept, but observation shows that differences in size have been closely correlated with yield; the apples on plot 3 have been small and those on plot 1 generally larger than those of any other plot. Rarely has the crop on any tree been large enough to limit the size of the fruit.

Brooks[1] reports near the end of the sod mulch period: —

> In color and general attractiveness of appearance the fruit of the several plots has usually ranked in the following order: plots 2, 5, 4, 1 and 3. In the early years of the experiment the rank of the fruit in size was in the order: plots 5, 4, 1, 2 and 3. At the present time (1909) the apples on plot 1 take a higher relative rank, and in all cases where the quantity of fruit is not excessive the apples on plot 1 are usually larger than on any of the other plots.
>
> A number of tests of keeping quality have been made, and in this respect the fruit has usually ranked in about the following order: plots 5, 4, 1, 2 and 3. The relatively low rank of the fruit from plot 2 in keeping quality appears to be connected with the fact that this fruit comes to maturity earlier than that on the other manured or fertilized plots. It will be noted that the fruit from plot 2 ranks highest in appearance. This is due to its superiority in coloring. This in turn is undoubtedly connected with the fact that the fruit is somewhat more mature. Such fruit might undoubtedly be kept if promptly put into cold storage; but in ordinary storage it is considerably inferior to the somewhat less thoroughly ripened fruit on the other manured plots.
>
> The fruit from plot 5 has almost invariably been much superior in appearance to that produced on plots 1 or 4. Here again there have been individual variations in the product of the different trees of the same variety on all of the different plots. There has, however, been no doubt as to the fact that on the whole the product of plot 5 has been considerably superior in color and general attractiveness as well as in firmness of flesh to the product from plot 4; while the product from plot 1, which receives barnyard manure, ranks below either of the others in the qualities just mentioned. In general, the fruit produced on plot 5 shows a considerably brighter and clearer color than that on either plots 4 or 1. There can be no doubt that it would sell at a higher price in the general market than either of the others, although the difference between plots 4 and 5 is considerably less than between plots 1 and 5. The product of the unmanured plot, 3, shows good color and in some cases is of fair size, but in general is too small to command the best prices.

At the present time, after ten years of strip cultivation, these differences between the several plots are not as marked as during the sod mulch period, yet they continue in considerably reduced degree.

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[1] Mass. Agr. Expt. Sta., Ann. Rept. 22, Pt. 2, p. 14 (1910).

The Graves Orchard.[1]

As the experiment above reported progressed, marked differences appeared between plots 4 and 5, the muriate and sulfate plots. Though these differences became less in later years, in 1907 they appeared important enough to justify further investigation. Accordingly a ten-year lease of a young Baldwin orchard, located in the southeastern part of the town of Amherst about six miles distant from the Experiment Station, was secured.

An experiment was planned to show whether differences similar to those which had appeared between plots 4 and 5 would appear here also, and whether, if such differences did appear, they were due to the form of the potash, which was muriate in one case and sulfate in the other, or to the presence of magnesium in the low-grade sulfate of potash.

The site of the orchard was a gentle northeasterly slope, with the steep slope of the easterly end of the Holyoke mountains about 40 rods to the south. The soil was a medium sandy loam rather low in fertility.

The trees, with the exception of four scattered trees, were of the Baldwin variety, and were said to be six years old at the beginning of the experiment. While most of the trees were fairly uniform at the start, there were a number of poor stunted trees which died or were replaced with new trees early in the experiment. None of these young trees bore fruit during the experimental period, and they are omitted in the consideration of the results. A plan of the orchard is shown in Fig. 9.

The orchard was in sod when taken over, but it was plowed in the spring of 1908, and in the following years handled in a system of cultivation and non-leguminous cover crops. As shown in the plan a strip on the north end was left in sod during the whole period.

Fertilizer Treatment.

In the spring of 1908 the orchard was laid out in eight plots of two rows each, and application of fertilizers made as shown in Fig. 9. Application of these materials at the given rates was made annually during the first half of May, beginning in 1908 and continuing for six years. In 1914 the applications to row 2 of each plot were discontinued, and the amounts given to row 1 of each plot reduced to one-half the former amounts. This plan was followed for four seasons until the expiration of the lease ended the experiment.

The circumference of the trunks 1 foot from the soil was taken in the spring of 1908; in April, 1914; in April, 1916; in November, 1917; and in August, 1921.

The first crop of fruit was produced in 1911. This was followed by a very light crop in 1912 and moderate crops in 1914, 1915, 1916 and 1917. Yield records were taken by plots, omitting the four odd trees mentioned

[1] This experiment was planned by Dr. Wm. P. Brooks, then director of the Experiment Station. The data were taken under the direction of Prof. F. C. Sears and E. F. Gaskill. The writer is responsible for the tabulation and interpretation of the data.

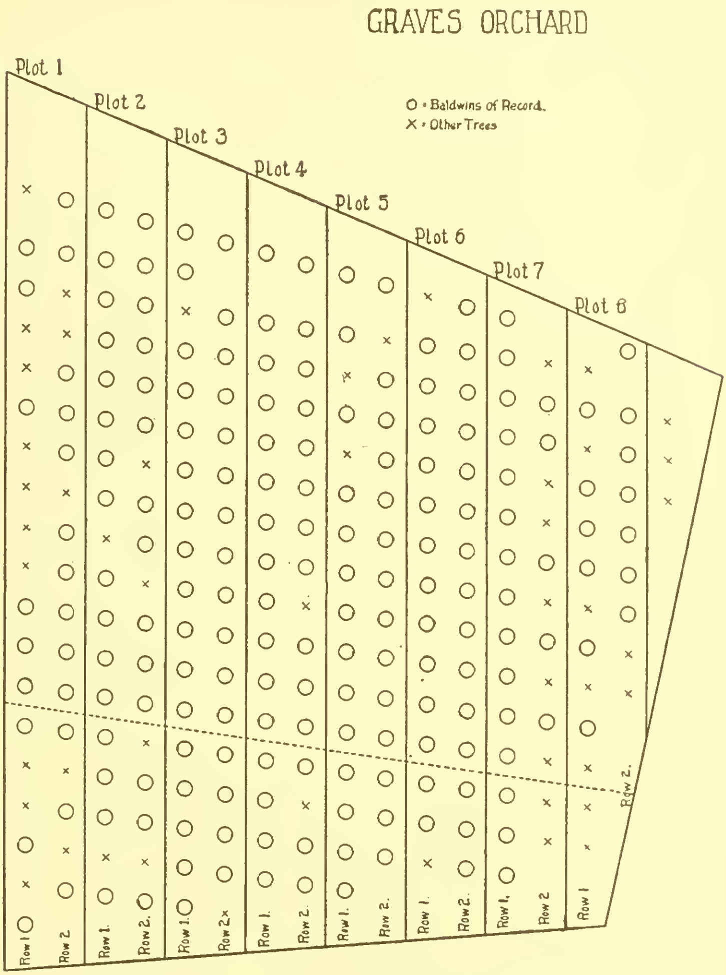

FIG. 9. — Plan of the Graves orchard. The portion below the dotted line was in sod.

Fertilizer Treatment per Acre.

Plot 1.	Manure	8 tons
Plot 2.	Ashes	1,600 pounds
Plot 3.	No fertilizer.	
Plot 4.	Bone	600 pounds
	Muriate of potash	160 pounds
Plot 5.	Bone	600 pounds
	Low-grade sulfate of potash	320 pounds
Plot 6.	Bone	600 pounds
	Muriate of potash	160 pounds
	Sulfate of magnesia	255 pounds
Plot 7.	Bone	600 pounds
	High-grade sulfate of potash	160 pounds
Plot 8.	Basic slag	800 pounds
	Low-grade sulfate of potash	320 pounds

above. Individual tree records of yield were not taken, nor was any separation made of the yields of that portion of the trees remaining in sod. In the early years no separate record of dropped and picked fruit was made, but in the last four years the picked fruit was recorded separately.

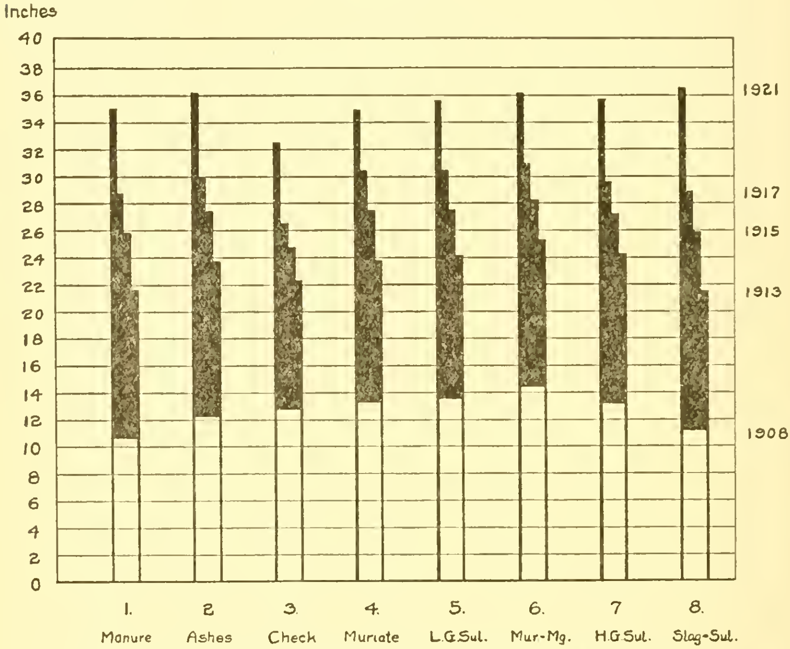

FIG. 10. — Average trunk circumference by plots, cultivated Baldwin trees only (Graves orchard).

Growth Records.

Fig. 10 shows the increase in trunk circumference of the trees in cultivation in the several plots. The growth on plot 3, the check plot, has been less than on the other plots, indicating that the trees responded to the application of all the fertilizers by increased growth. At the beginning of the experiment the trees on plot 3 were exceeded in size by those on plots 4, 5, 6 and 7. In 1917, at the end of the period of fertilization, this difference had increased somewhat, while the trees on plots 1, 2 and 8 had grown so that the check plot then had the smallest trees of any plot. A later measurement of the same trees made in August, 1921, showed that the check trees were still the smallest. It is interesting to note that plots 1, 2 and 8 are the only plots that showed greater growth than the check plot in this four-year post-experimental period.

One seems justified in concluding that on these Baldwin trees under cultivation the fertilizer applications have caused greater growth, and that manure and lime-carrying fertilizers have been more beneficial than those chemical fertilizers which carried no lime.

As has been stated, there was a strip across the north ends of the plots that remained in sod during the entire experimental period. The trees on this strip made considerably less growth than those in cultivation, as shown in Table 2.

TABLE 2. — *Average Increase in Trunk Circumference, 1908–17.*

Plot.	Treatment.	Trees in Sod.		Trees in Cultivation.	
		Number.	Increase in Circumference.	Number.	Increase in Circumference.
1	Manure	6	15.2	16	18.1
2	Ashes	7	14.5	24	17.6
3	No fertilizer	9	11.0	25	13.7
4	Bone and muriate	7	12.6	23	17.2
5	Bone and low-grade sulfate	9	12.1	21	16.9
6	Bone, muriate and magnesia	7	12.8	23	16.4
7	Bone and high-grade sulfate	4	14.5	17	16.4
	Averages and totals	49	13.3	149	16.6

The trees on plot 7 made relatively more growth in sod than those on the other fertilized plots, but owing to the small number of trees involved there is a question if the difference is significant. With this one exception the two series of plots parallel each other very closely. The parallel between plots 4 and 5 is very close. As previously stated, there was some indication that in the station orchard, under sod or sod mulch conditions, low-grade sulfate of potash was superior to muriate. In this orchard, what slight difference there is is reversed in both the sod and cultivated portions of the plots.

It has been stated that in 1914 and following years row 2 of each plot received no fertilizer, while row 1 of each plot received only one-half the amounts previously applied. Table 3 shows the average increase in trunk circumference of the trees in cultivation; no dependable comparison can be made of those in sod because of too few trees.

TABLE 3. — *Average Trunk Circumference of Trees in Cultivation, All Plots except Check (Inches).*

Row.	Treatment.	1913.	1915.	1917.
1	One-half previous amounts	23.50	27.26	30.19
2	No fertilizer	22.94	26.68	29.24
	Difference	.56	.58	.98

These figures indicate a slight response in circumference increase apparently due to the fertilizers, but not enough to be of much significance.

Yield Records.

The yield records of this orchard have been kept by plots only. Inasmuch as the plots are of different sizes and include different numbers of trees, it seems best to divide the total plot yields by the number of bearing trees, thus obtaining the average yield per tree. The average total yield per tree is shown in Table 4.

TABLE 4. — *Average Yields per Tree (Pounds).*

Plot.	Treatment.	1911.	1912.	1914.	1915.	1916.	1917.	Average.
1	Manure	92	15	117	224	328	158	156
2	Wood ashes	217	44	211	221	316	133	191
3	No fertilizer	234	67	101	188	102	223	153
4	Bone and muriate . . .	188	38	66	390	213	268	194
5	Bone and low-grade sulfate . .	114	55	334	212	347	141	201
6	Bone, muriate and magnesia .	251	58	418	195	332	191	241
7	Bone and high-grade sulfate .	279	45	338	260	200	159	214
8	Slag and low-grade sulfate . .	163	11	334	175	387	221	215

The lowest yield is from the unfertilized plot, 3, and the highest yield is from the muriate and magnesium plot, 6. Plots 4 to 8 show rather uniform yields, varying from 194 to 241 pounds per tree, and it is probably unsafe to attribute the differences that do show to the differential fertilizer treatment. The yield from the ashes plot (189 pounds) is only a little below that of these plots, and may or may not indicate that this fertilizer treatment was less effective in producing apples than the treatments given to plots 4 to 8. The yield on the manure plot is low and may indicate an inferiority of manure as fertilizer on this soil, yet it should be noted that these trees were at first the smallest in the orchard, and at the end of the experimental period were exceeded in trunk circumference by all except those on the unfertilized plot. Plots 4 and 5 received practically the same fertilizer treatments as plots 4 and 5 in the station orchard, the results from which this experiment was planned to explain. The difference in yield is here only 7 pounds per tree, a degree of similarity rarely secured from plots receiving identical fertilizer treatments.

Fig. 11 shows the average yield per tree by two-year periods, — 1911 and 1912, 1914 and 1915, and 1916 and 1917, — there being no crop in 1913. The most significant fact brought out here is that the unfertilized plot shows practically the same yield for each period, while the fertilized plots all show substantial gains for the second two periods over the first. The slag-sulfate plot, 8, shows a large gain, and the manure plot, 1, makes a better showing from this viewpoint than from that of average total yields per tree. The ashes plot, 2, made a substantial gain during the second period, but made little further gain in the third period.

It seems reasonable to conclude that under the conditions at this orchard, which is on a sandy soil of inferior fertility, as indicated by the growth of cover crops and other herbaceous plants, the fertilizers applied have been beneficial to the trees, as indicated by increased growth and greater production.

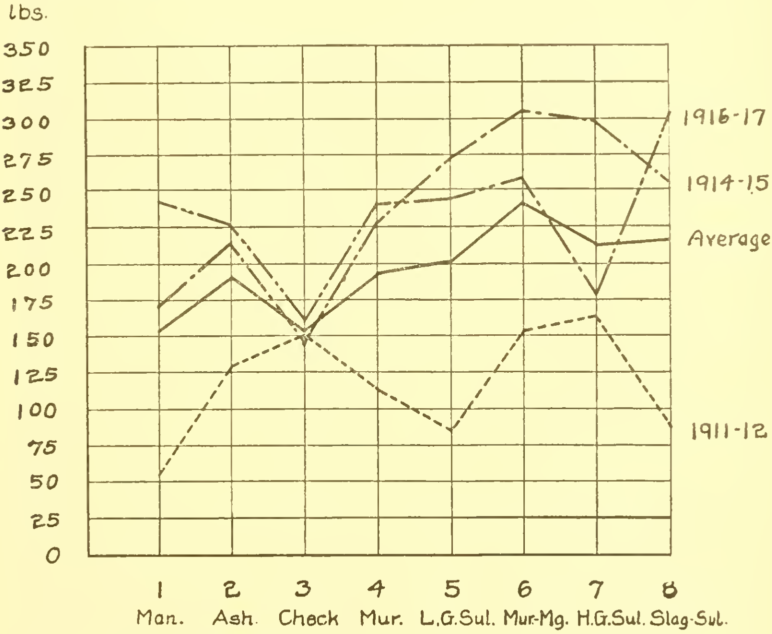

FIG. 11. — Average yield per tree by two-year periods (Graves orchard).

Discussion of Results.

The results of many orchard fertilizer experiments in this country have shown that, of all the fertilizer elements usually taken into consideration, nitrogen is most likely to produce a response. This response appears in darker colored and more luxuriant foliage, more growth, and often increased production of fruit. It may be worth while to consider how far the observed results, especially those of growth, can be explained on the basis of variation in available nitrogen supply.

The manure plot in the station orchard has plainly responded to the generous supply of nitrogen it has received. Growth, foliage color, and size and color of fruit have all been typical of trees well supplied with nitrogen. Both the potash plots in this orchard have received small supplies of nitrogen in the ground-bone application of 600 pounds per acre. This amount of bone supplies only about one-tenth as much nitrogen as plot 1 has received, and yet it is doubtless enough to account in part, at least, for the greater growth than that observed on the unfertilized plot. The uniformity of the several potash plots in the Graves orchard indicates that this may have been a nitrogen response rather than one to potash. All indications are that the Graves orchard soil is deficient in nitrogen, and a small supply of this element might be expected to produce marked results.

The relatively strong growth of the trees on the ashes plots and on the slag-sulfate plot in the Graves orchard indicates that added nitrogen cannot wholly account for the greater growth of the fertilized trees. Probably the presence of lime has favored greater availability of the nitrogen-carrying humus, even though this may have been present in only small amount in this soil, and so operated to increase the nitrogen available for the trees. The striking response to cultivation of the trees on the unfertilized plot in the station orchard may be fairly taken to indicate that lime is not always necessary to render the humus nitrogen available.

Manure has had a more persistent residual effect in both orchards than the other materials used. Evidently the effect of greater nitrogen supply because of cultivation, on plots not receiving manure, lasted about five years, after which the nitrogen supply was insufficient to maintain the increased growth of the trees.

The fact of inferior growth and production of the muriate plot in the station orchard as compared with the low-grade sulfate plot is interesting, and seems to have been peculiar to sod mulch management. Its inferiority apparently disappeared when the soil was cultivated. There is no evidence of such a difference on the lighter, better-drained soil of the Graves orchard. It is probable that this superiority of the low-grade sulfate was a real one. It has been suggested that the difference was due to the poorer drainage of the muriate plot. But the adjoining unfertilized plot is still more inferior in this respect, and yet this plot gave very good results when strip cultivation was adopted. It has been shown that muriate of potash may exert a depressing effect on nitrification, and this may possibly explain the results obtained. The attempt to explain whether this difference was due to the difference in the form of potash or to the presence of magnesium in the low-grade sulfate was unsuccessful, as no significant differences were obtained in the Graves orchard even with the trees in sod. The Graves orchard received a lighter application of potash and for a shorter period of years. Possibly this may have been a factor in bringing about different responses.

Summary.

1. In the two orchard experiments here reported, growth and fruit production were closely correlated. Increased growth was followed by increased production.

2. In one of the orchards, trees in cultivation gave better growth and higher production than when in sod.

3. In a sod orchard, low-grade sulfate of potash gave better results than muriate of potash, both plots receiving also ground bone. With strip cultivation this difference seemed to disappear. In a cultivated orchard, on lighter, better-drained soil, no significant differences appeared. On the sod portion of this second orchard, furthermore, there were no material differences.

4. The residual effect of manure was greater than that of ashes or the chemical fertilizers used.

APPENDIX.

Here are given the original data on which the discussion in this paper is based.

TABLE I. — *Station Orchard: Tree Circumferences (Inches).*

Rhode Island Greening.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 28.0			Av. 25.5			Av. 23.2			Av. 23.7			Av. 26.2		
1903[1]	Av. 30.3			Av. 27.0			Av. 23.6			Av. 25.9			Av. 27.0		
1904[1]	Av. 33.0			Av. 29.8			Av. 26.1			Av. 28.2			Av. 30.8		
1907	36.5	34.3	38.8	33.5	29.5	37.0	26.5	20.8	34.3	30.0	23.0	35.5	29.0	34.5	34.0
1908	39.0	38.0	41.0	35.0	30.8	39.3	28.0	21.5	35.8	31.5	25.0	37.0	31.5	36.5	37.0
1909	40.5	40.0	42.5	36.5	32.0	40.8	28.5	21.5	36.8	32.5	26.5	38.5	32.5	38.5	37.8
1911	44.0	44.3	45.5	38.5	35.0	43.8	30.5	23.3	39.5	35.5	29.8	41.3	35.0	41.8	40.3
1913	46.0	48.5	48.0	42.5	37.0	47.5	32.0	25.0	43.0	37.5	32.0	43.3	36.0	42.5	44.0
1914	48.0	49.5	49.3	44.5	38.5	49.8	33.8	26.0	44.3	38.8	33.8	44.8	36.8	44.5	46.0
1915	49.3	52.3	51.3	46.8	40.0	51.3	36.0	27.5	46.5	40.0	35.8	46.0	38.3	45.0	47.5
1916	52.3	55.5	54.0	49.5	42.0	54.0	37.5	29.3	49.5	42.0	37.5	48.0	39.8	47.3	50.0
1917	52.5	55.5	54.0	50.0	42.3	55.0	38.3	30.3	49.8	42.3	38.0	48.0	40.0	47.5	50.0
1919	56.0	59.5	57.8	54.3	46.8	57.5	40.5	32.8	53.0	43.0	40.5	49.5	42.0	50.0	53.0
1920	57.5	59.8	58.5	55.5	45.8	58.3	41.3	33.5	53.5	44.0	41.5	50.8	43.0	51.5	54.5

Roxbury Russet.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 23.2			Av. 22.3			Av. 20.0			Av. 23.3			Av. 23.8		
1903[1]	Av. 24.0			Av. 23.0			Av. 20.4			Av. 24.0			Av. 24.8		
1904[1]	Av. 26.8			Av. 25.0			Av. 22.6			Av. 26.4			Av. 26.9		
1907	30.0	29.5	30.0	27.5	28.5	27.0	21.0	26.0	24.0	28.8	33.5	23.3	30.5	29.5	28.0
1908	32.0	31.5	30.5	28.5	29.5	28.3	22.0	27.5	25.5	30.0	35.0	23.3	32.0	30.8	29.8
1909	32.8	32.8	32.8	29.8	30.5	29.3	22.5	28.5	26.8	31.0	36.3	[2]	33.0	31.8	30.5
1911	35.0	36.0	37.0	32.5	32.8	32.0	24.5	31.3	29.0	34.8	40.0		35.5	34.0	33.5
1913	37.8	38.8	39.5	34.5	34.5	33.0	25.5	33.0	31.0	36.5	41.3		37.0	36.0	35.0
1914	39.3	40.3	40.5	35.8	35.5	34.0	28.8	33.5	31.8	37.8	45.3		38.0	37.3	36.0
1915	40.5	41.3	41.5	37 0	37.0	36.0	28.0	34.5	32.5	39.5	43.8		39.8	38.5	37.5
1916	42.5	43.0	44.0	38.5	38.8	37.5	28.8	36.3	33.3	40.5	45.0		40.5	39.8	39.0
1917	42.5	43.0	45.0	38.5	38.8	37.5	29.0	36.3	33.5	40.5	45.0		40.8	40.0	39.0
1919	45.5	45.3	47.5	40.5	40.3	39.0	30.3	37.3	35.0	42.3	46.0		42.8	42.3	40.5
1920	47.3	46.8	48.5	[2]	41.0	39.8	31.0	37.8	36.0	43.3	47.8		43.8	43.3	41.8

[1] Measurements of individual trees for these years not available. [2] Tree died.

TABLE I. — *Station Orchard: Tree Circumferences (Inches)* — Concluded.

Baldwin.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 27.7			Av. 22.3			Av. 18.2			Av. 19.3			Av. 29.8		
1903[1]	Av. 29.1			Av. 23.3			Av. 19.0			Av. 20.3			Av. 31.2		
1904[1]	Av. 32.5			Av. 25.9			Av. 21.4			Av. 23.1			Av. 34.3		
1907	36.5	36.0	34.0	28.8	25.5	31.3	24.8	23.5	19.8	21.5	30.0	23.5	38.0	33.0	40.3
1908	39.5	39.0	36.0	30.0	27.5	32.8	25.5	25.5	21.0	23.0	32.0	25.3	40.0	34.5	42.8
1909	40.5	40.0	36.5	31.0	28.3	34.0	26.0	26.5	23.0	24.0	33.3	26.3	41.8	35.5	44.0
1911	44.0	44.8	41.0	33.0	31.3	36.0	28.0	29.0	23.8	27.8	36.5	28.5	45.3	38.0	47.5
1913	47.0	47.3	41.0	35.5	34.0	39.0	29.5	34.0	24.0	28.5	39.0	30.8	48.8	39.5	51.0
1914	48.0	48.5	42.3	37.0	35.3	40.0	30.8	35.5	[2]	29.8	40.0	32.0	50.5	41.0	52.0
1915	49.5	50.0	43.3	38.5	37.0	41.5	32.3	38.0		31.0	42.0	33.5	52.0	42.8	53.5
1916	51.5	52.5	45.0	40.0	39.0	43.0	33.5	40.3		32.5	43.5	35.3	53.5	43.3	55.5
1917	52.5	53.3	45.3	40.5	39.5	43.0	33.8	41.0		32.8	44.3	36.0	54.0	43.5	55.8
1919	54.8	56.5	47.0	42.3	41.5	44.5	35.5	44.0		34.8	46.3	37.5	56.0	44.8	58.0
1920	56.8	58.3	48.0	43.3	42.5	45.5	36.5	46.0		35.3	47.5	38.5	56.8	46.0	60.0

Gravenstein.

Tree.	Plot 1.			Plot 2.			Plot 3.			Plot 4.			Plot 5.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1902[1]	Av. 29.5			Av. 25.3			Av. 24.0			Av. 24.8			Av. 28.5		
1903[1]	Av. 31.0			Av. 26.3			Av. 24.5			Av. 25.9			Av. 28.5		
1904[1]	Av. 33.8			Av. 29.4			Av. 28.0			Av. 30.1			Av. 32.6		
1907	36.0	40.0	2.5	30.3	32.5	34.0	26.0	29.0	31.8	31.0	35.0	30.5	33.0	37.8	35.5
1908	39.3	42.0	3.5	32.0	34.0	35.8	27.0	30.8	34.0	32.5	37.5	32.3	35.0	39.5	37.3
1909	40.5	42.0	3.5	33.5	35.8	37.5	28.5	32.0	35.3	34.3	39.5	33.0	36.8	42.0	40.3
1911	43.8	46.3	7.0	36.0	38.5	40.3	30.5	34.5	37.3	37.5	43.5	36.0	40.3	43.8	43.0
1913	47.5	49.5	12.0	39.5	42.5	43.0	34.0	37.8	43.0	39.5	47.0	37.5	41.8	48.5	45.0
1914	48.0	52.5	12.0	41.0	43.8	44.3	35.3	39.3	44.8	41.5	48.0	38.5	43.5	50.3	46.8
1915	49.0	53.5	[2]	43.0	45.5	45.8	37.5	41.5	47.0	43.0	50.0	40.0	44.8	52.0	48.5
1916	50.5	56.5		45.0	47.8	47.5	39.0	43.0	50.0	45.0	52.3	41.3	46.0	54.0	50.5
1917	50.5	60.0		45.8	48.0	47.8	39.3	44.0	51.0	45.3	52.5	41.5	46.0	54.8	51.0
1919	50.0	64.0		48.0	50.3	50.0	42.0	46.8	54.5	47.3	55.5	44.3	48.5	59.0	53.3
1920	[2]	66.5		49.3	51.3	51.0	43.3	48.8	55.5	48.8	57.0	45.3	49.5	61.0	55.5

[1] Measurements of individual trees for these years not available. [2] Tree died.

TABLE II. — *Station Orchard: Total Yields by Plots (Pounds).*

Rhode Island Greening.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	270	45	41	130	85	571
1902	777	272	65	521	260	1,895
1903	970	891	394	435	945	3,635
1904	972	139	34	566	297	2,008
1905	596	168	101	338	79	1,282
1906	274	39	27	419	52	811
1907	1,496	973	226	760	798	4,253
1908	948	232	85	328	270	1,863
1909	2,157	1,165	140	604	1,087	5,153
1910	806	334	84	146	101	1,471
1911	1,777	1,162	274	815	1,117	5,145
1912	864	922	811	1,220	747	4,564
1913	1,546	2,196	718	1,354	2,111	7,925
1914	325	194	93	259	189	1,060
1915	2,859	2,467	1,109	2,271	2,240	10,946
1916	761	338	378	188	210	1,875
1917	3,370	2,820	1,191	1,846	1,813	11,040
1918	123	226	135	124	76	684
1919	3,150	2,389	1,097	1,529	1,055	9,220
1920	3,991	2,758	1,812	1,580	1,440	11,581

TABLE II. — *Station Orchard: Total Yields by Plots (Pounds)* — Concluded.

Roxbury Russet.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	269	119	39	251	291	969
1902	874	631	269	1,235	1,023	4,032
1903	703	567	330	608	1,067	3,275
1904	391	384	5	396	410	1,586
1905	548	206	165	621	769	2,300
1906	128	61	8	26	68	291
1907	1,361	1,295	313	903	1,389	5,261
1908	328	78	71	270	232	979
1909	1,719	547	90	991	1,172	4,519
1910	372	403	331	149	135	1,390
1911	1,139	639	31	560	828	3,197
1912	1,055	703	466	1,043	914	4,181
1913	1,963	1,128	754	1,629	2,390	7,864
1914	161	447	57	329	458	1,452
1915	2,398	1,984	400	1,311	2,066	8,159
1916	566	535	293	821	595	2,810
1917	1,942	1,455	345	802	1,045	5,589
1918	9	39	453	209	25	735
1919	2,839	922	1,057	722	753	6,293
1920	1,190	407	729	98	151	2,575

Baldwin.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	151	43	3	46	475	718
1902	43	207	0	114	548	912
1903	1,043	705	55	228	1,400	3,431
1904	231	18	51	98	577	975
1905	1,024	277	43	165	474	1,983
1906	4	128	33	26	634	825
1907	1,718	1,102	189	561	2,514	6,084
1908	110	106	88	25	280	609
1909	2,590	695	132	682	2,443	6,542
1910	41	469	8	22	121	661
1911	1,213	405	133	392	1,470	3,613
1912	683	1,264	205	537	1,176	3,865
1913	2,546	655	663	514	2,017	6,395
1914	371	820	36	690	765	2,682
1915	2,425	1,381	354	637	2,389	7,186
1916	333	910	99	479	1,178	2,999
1917	2,125	1,145	412	695	1,694	6,071
1918	315	1,046	261	528	480	2,630
1919	3,430	2,040	1,425	1,148	2,835	10,878
1920	625	964	60	6	82	1,737

Gravenstein.

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Totals.
Before 1902	75	15	27	51	43	211
1902	196	3	65	91	57	412
1903	884	531	110	518	347	2,390
1904	44	10	22	84	103	263
1905	225	231	201	614	365	1,636
1906[1]	–	–	–	–	–	–
1907	775	482	162	572	709	2,700
1908	265	347	189	431	184	1,416
1909	1,180	284	224	1,217	1,192	4,097
1910	50	514	199	41	27	831
1911	612	282	291	793	1,008	2,986
1912	24	402	377	25	50	878
1913	1,922	976	897	2,736	1,474	8,005
1914[1]	–	–	–	–	–	–
1915	694	1,472	778	1,685	1,149	5,778
1916	16	199	79	54	50	398
1917	479	1,475	1,223	1,432	1,036	5,645
1918	37	53	209	26	39	364
1919	370	1,054	979	912	1,012	4,327
1920	297	224	747	305	365	1,938

[1] No crop.

Table III. — *Graves Orchard: Trunk Circumferences of Individual Trees (Inches).*

	Plot 1.		Plot 2.		Plot 3.		Plot 4.		Plot 5.		Plot 6.		Plot 7.		Plot 8.	
Row.	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1908		6.3	10.0	8.0	14.5	11.5	9.5	11.0	12.0	17.0		10.0	10.0			
1913		11.0	19.5	16.5	22.3	19.8	17.8	18.8	20.5	29.6		17.3	17.0			
1915		13.8	23.5	20.5	24.5	23.0	22.5	22.0	23.8	33.5		17.8	19.0			
1917		16.8	25.8	24.0	25.5	25.0	26.5	24.0	25.5	36.0		19.5	20.5			
1921			32.0	30.5	31.5	30.8	30.8	28.5	33.0	44.0		24.5	24.8			
1908	6.0	9.0	7.3	14.0	14.0											
1913	14.8	18.0	18.1	27.9	24.9											
1915	19.0	21.5	22.5	31.5	27.5											
1917	23.5	24.5	25.8	34.0	30.0											
1921	29.5	30.0	33.0	38.5	36.0											
1908	10.0		14.0	15.0		12.5	13.5	15.0	2.8		11.5	13.0	14.5			10.0
1913	20.5		28.3	29.1		22.8	30.0	29.4	9.0		22.6	19.8	24.4			17.5
1915	24.8		32.0	33.5		25.8	33.3	33.0	13.5		27.5	21.3	26.5			
1917	28.0		34.0	35.5		28.0	37.5	36.0	18.3		30.0	23.5	29.0			23.0
1921	31.8		39.0	41.3		33.5	42.3	41.8	24.5		37.0	28.3	32.3			29.8
1908			11.5	8.0	12.5	11.5	12.0	11.0		10.0	17.0	10.0	18.0	11.0	17.0	11.0
1913			24.0	18.3	25.9	19.3	21.5	18.8		20.8	27.4	17.8	27.1	19.8	32.5	22.0
1915			28.0	22.0	28.8	21.0	24.8	21.5		24.0	30.8	20.0	30.5	22.8	37.5	26.5
1917			31.0	25.0	31.0	23.0	27.5	23.5		27.0	34.0	22.8	33.0	25.0	40.0	30.5
1921			37.0	29.5	37.5	27.5	31.3	27.8		30.5	40.0	27.0	37.5	31.5	48.8	37.0
1908		13.0	11.5	14.5	14.5	11.5	15.0	13.5	13.0	10.5	15.5	18.0	16.0	17.0		11.0
1913		25.3	26.1	29.0	26.5	16.3	25.1	25.0	22.0	20.9	28.4	31.0	28.8	28.8		23.5
1915		30.0	30.5	31.8	29.5	17.5	29.0	29.8	25.8	25.0	32.0	33.3	31.8	32.0		27.8
1917		32.8	33.3	34.0	31.0	18.3	32.0	32.0	28.3	26.5	34.0	37.5	34.0	34.5		30.5
1921		39.8	38.0	39.8	37.8	20.5	37.8	37.5	32.0	31.5	40.3	42.8	40.5	40.0		38.3
1908	8.8	11.0	9.0	13.0	13.0	10.0	12.0	15.0		17.0	12.5	16.0	16.0		15.5	8.5
1913	18.0	24.0	19.4	23.8	25.5	15.5	20.0	24.6		31.0	21.4	28.5	27.8		27.0	13.5
1915	22.3	28.5	22.0	27.3	28.3	16.0	23.5	28.0		35.8	23.0	31.5	31.3		31.3	16.0
1917	25.5	32.0	24.3	28.3	31.5	17.8	24.8	30.0		38.8	25.0	35.5	33.0		35.5	18.5
1921	31.5	38.8	30.0	32.5	37.5	19.8	29.5	36.5		47.0	30.3	39.5	39.8		40.5	24.3
1908		11.0	12.0		13.5	12.0	15.0	14.5	14.0	17.5	17.0	15.5	13.5		13.5	13.5
1913		23.0	23.1		24.1	21.0	21.9	25.8	21.3	29.8	29.0	23.0	21.5		25.1	22.4
1915		28.3	26.8		29.0	23.5	24.0	29.5	24.5	34.0	31.8	24.8	23.3		30.5	25.0
1917		31.8	29.5		32.0	24.0	25.0	32.3	26.5	37.0	35.0	26.0	25.0		34.5	28.0
1921		37.5	35.0		38.3	30.0	28.8	38.0	31.3	42.0	39.8	31.0	27.8		39.5	34.3
1908			12.5	9.0	17.0	13.0	13.0	14.0	12.5	9.5	17.5	16.0	12.0	6.0	11.0	9.0
1913			22.3	17.8	28.0	23.6	23.5	23.8	21.0	17.3	30.5	26.5	19.5	8.9	24.1	18.6
1915			25.8	20.5	30.3	25.3	26.5	26.5	23.0	19.5	34.8	29.0	21.8	10.0	28.0	22.3
1917			28.0	23.5	31.0	27.0	28.5	29.0	24.5	21.0	37.3	31.8	23.8	10.8	31.0	26.0
1921			33.0	28.0		30.8	31.3	35.5	27.5	27.5	43.0	38.0	27.3		37.0	32.5
1908		13.0		13.5	14.0	13.0	13.0	14.5	15.0	16.0	12.0	17.0	14.5			12.0
1913		25.0		25.0	21.0	19.0	24.5	22.9	27.1	27.6	28.9	28.5	25.0			24.0
1915		29.8		29.5	23.0	20.5	28.8	25.8	32.0	30.5	32.3	32.5	29.0			28.5
1917		31.5		33.0	25.0	22.0	30.5	28.8	35.0	32.0	34.5	35.5	31.0			32.0
1921		37.3		39.8	29.3	24.8	36.5	34.0	41.3	38.0	39.5	41.8	36.0			38.8
1908		13.5	14.0		16.0	15.5	14.5		12.0	15.5	14.0	13.5	14.0	15.0	13.0	
1913		26.0	26.3		24.8	25.8	28.6		22.9	27.5	24.5	24.0	24.1	26.5	26.0	
1915		30.0	30.0		26.3	28.8	32.3		26.3	30.8	27.5	26.3	27.5	30.8	31.0	
1917		33.5	33.5		28.0	31.0	34.5		28.5	33.5	30.0	29.5	29.5	33.5	34.0	
1921		38.5	39.0		33.8	36.5	41.3		35.3	38.5	35.0	34.5	34.8	39.8	39.3	
1908	12.5	12.5	17.0	15.0	10.0	14.0	10.5	16.0	16.0	11.0	15.5	15.0	17.5			
1913	25.5	25.0	30.5	29.0	21.0	24.6	21.0	28.0	28.9	22.5	24.4	27.1	29.8			
1915	30.5	28.5	34.3	33.5	23.5	27.3	24.8	32.3	32.0	25.5	27.0	31.0	33.5			
1917	33.5	28.5	37.0	36.5	25.3	30.0	27.0	36.0	35.0	27.0	29.3	34.5	36.0			
1921	39.3	33.0	42.0	41.5	30.3	35.5	31.3	40.5	41.0	31.5	34.0	38.8	40.8			
1908	10.5	13.0	16.5	14.0	13.5	14.5	13.5	14.0	14.0	16.0	14.0	15.5	17.5	13.0	8.0	
1913	22.8	26.3	30.9	25.0	24.8	24.1	26.0	25.1	23.3	27.0	26.3	26.8	29.5	26.5	19.0	
1915	29.5	31.0	36.0	28.8	28.8	27.0	30.5	28.8	26.5	30.3	29.5	30.5	32.8	31.3	22.8	
1917	30.5	34.8	39.0	31.0	32.0	29.5	33.0	32.0	28.0	31.5	32.0	33.0	35.0	34.0	26 3	
1921	37.0	39.8	44.5	37.0	37.3	35.5	38.0	37.5	32.8	38.0	37.5	39.0	39.8	40.0	32.5	

TABLE III. — *Graves Orchard: Trunk Circumferences of Individual Trees (Inches)* — Concluded.

Row.	Plot 1.		Plot 2.		Plot 3.		Plot 4.		Plot 5.		Plot 6.		Plot 7.		Plot 8.	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1908	8.5	12.0	14.0	11.5	16.5	11.5	10.0	14.0	15.0	17.5	13.0	15.0	14.5			
1913	21.3	20.8	25.5	23.5	29.8	20.0	21.0	26.5	25.9	29.0	23.0	27.3	27.6			
1915	25.5	23.3	29.5	27.0	33.8	22.8	24.8	30.0	30.0	33.0	25.5	30.8	31.0			
1917	28.0	25.0	31.5	30.0	36.0	23.5	27.8	32.5	33.0	35.3	27.5	34.0	34.5			
1921	31.0	29.5	35.8	36.8	41.3	30.5	32.0	36.0	39.0	40.5	31.8	38.5	39.0			
1908	7.5	12.0	14.0		15.5	12.0	13.0	16.0	15.0	11.0	12.5	14.0	14.0			
1913	19.0	21.8	26.5		25.5	19.0	21.0	24.5	23.5	16.5	20.4	21.8	24.0			
1915	19.5	24.3	29.8		28.8	20.8	23.8	28.8	26.5	17.8	23.0	24.0	25.8			
1917	22.0	26.0	32.5		30.8	23.0	25.5	31.3	28.8	18.5	25.0	26.0	28.5			
1921	28.5	32.0	38.0		37.8	26.5	29.0	35.8	33.5	23.5	30.0	31.5	35.5			
1908			11.0	15.0	15.0	14.0	14.0		14.5	11.0	10.0	15.5	16.0			
1913			16.8	25.5	21.6	20.5	22.9		21.0	20.4	17.0	21.5	24.0			
1915			18.0	27.8	23.3	23.3	25.0		22.5	22.5	20.0	23.0	26.3			
1917			19.5	29.3	24.3	29.0	28.0		24.3	26.0	22.0	23.0	28.0			
1921			25.0	33.3	32.0	32.0	32.0		28.0	31.5	28.3	31.3	35.8			
1908		8.5	10.0	14.0	13.5	14.0	16.0	9.0	11.0	11.5		13.0	11.0			
1913		15.0	19.4	22.5	21.0	19.0	24.6	14.8	17.9	15.6		19.5	16.9			
1915		17.3	22.5	25.0	22.3	20.5	26.0	16.5	19.5	19.8		22.3	20.3			
1917		20.5	25.5	27.0	25.0	21.5	27.8	19.5	21.5	18.0		25.0	22.5			
1921		28.5	32.5	32.5	31.3	28.0	31.5	25.8	27.5			32.0	29.8			
1908	5.0				12.0	15.0	12.5	13.5	12.0							
1913	12.3				18.5	21.6	18.8	22.1	15.0							
1915	15.5				20.3	22.3	19.8	25.5	18.3							
1917	19.3				22.0	24.5	22.0	28.0	20.8							
1921	27.8				29.3	28.3	27.0	35.8	28.8							
1908		11.0	13.5	15.0	14.5											
1913		23.3	23.9	24.0	20.0											
1915		26.3	26.8	27.5	19.5											
1917		30.3	29.5	30.5	20.5											
1921		36.8	38.5	39.0	25.8											
1908	9.0															
1913	17.8															
1915	21.5															
1917	26.0															
1921	32.5															

TABLE IV. — *Graves Orchard: Yield of Baldwin Trees (Pounds).*

Plot.	Row.	Number of Trees.	1911.	1912.	1914.	1915.	1916.	1917.
1	1	9			1,215	1,114	3,040	1,056
	2	13			1,357	3,817	4,191	2,433
	Total	22	2,023	326				
2	1	16			4,000	3,866	5,780	2,736
	2	14			2,331	2,773	3,719	1,269
	Total	30	6,519	1,307				
3	1	17			2,380	3,993	2,294	4,549
	2	16			964	2,199	1,069	2,806
	Total	33	7,734	2,216				
4	1	16			801	6,154	3,230	4,569
	2	14			1,175	5,560	3,154	3,484
	Total	30	6,540	1,125				
5	1	14			3,410	2,237	4,796	1,121
	2	14			5,944	3,706	4,922	2,827
	Total	28	3,179	1,642				
6	1	13			6,073	1,974	4,886	2,294
	2	15			5,648	3,475	4,413	3,059
	Total	28	7,040	1,625				
7	1	15			5,697	4,076	3,183	1,624
	2	5			1,070	1,125	827	1,561
	Total	20	5,581	907				
8	1	6			3,213	1,230	3,868	1,114
	2	7			1,130	1,052	1,164	1,766
	Total	13	2,124	146				

TECHNICAL BULLETIN No. 5.

DEPARTMENT OF VETERINARY SCIENCE.

CONCERNING THE DIAGNOSIS OF BACTERIUM PULLORUM INFECTION IN THE DOMESTIC FOWL.

BY GEORGE EDWARD GAGE.

During the years 1916, 1917, 1919 and 1920 special studies have been conducted in this department concerning the diagnosis of *Bact. pullorum* infection in chicks and adult birds. The object in view has been to determine factors which aid in accuracy of diagnosis. Therefore the plan here is to set forth the data obtained which may be of some value in substantiating the work of others, and to add any data from experimental studies and routine which may assist those who have to do with the pullorum problem.

Among the points to be considered by the laboratory and field worker in the *Bact. pullorum* problem, the following are of interest: —

1. Are there a *Bacterium pullorum* A and a *Bacterium pullorum* B?
2. Can infections with *Bacterium pullorum* and *Bacterium sanguinarium* be differentiated?
3. Is *Bacterium sanguinarium* (fowl typhoid) widely distributed in Massachusetts?
4. Is it necessary to submit suspicious *Bacterium pullorum* cultures to biochemical tests before a diagnosis is justified?
5. Is either *Bacterium pullorum* or *Bacterium sanguinarium* related to the so-called "paralysis" so widely distributed at certain periods of the year in Massachusetts?
6. Is *Bacterium sanguinarium* of any significance as the cause of epidemic disease in very young chicks?
7. What is the present status of the specificity of the agglutination test as a means of control of *Bacterium pullorum* infection in young chicks?

Historical.

The presence of cholera-like or typhoid-like epidemics in domestic birds dates back many years, but careful study extends only from the last quarter of a century. For a most excellent historical résumé of these studies from 1789 to 1913, the reader is referred to Hadley (1).

Since 1913 several investigators have added much to our knowledge concerning the biology of *Bact. pullorum*. Smith and Ten Broeck (2), carrying out five sets of experiments in which serum of rabbits immunized with heated cultures of human typhoid, fowl typhoid and *Bact. pullorum*, considered that the agglutination tests were sufficiently definite to enable them to group the fowl typhoid and pullorum types together, both demonstrating the same intimate relation to typhoid bacilli. Again, in another paper (3), these writers demonstrated that fowl typhoid has many diagnostic features in common with the human typhoid bacillus, namely, the behavior toward carbohydrates and the agglutination reactions.

Rettger and Koser (4) carried out agglutination tests using reacting sera from rabbits immunized by subcutaneous injections, first of killed suspensions and later of living suspensions of *Bact. pullorum* and *Bact. sanguinarium*. Five days after the injections of heated vaccine, the rabbits were bled and the agglutinative power of the sera tested against definite suspensions of both *Bact. pullorum* and *Bact. sanguinarium*. No difference in agglutination properties was manifested. Attempts were made to increase the agglutination titre by the injection of living organisms. The titre remained the same and no change in the agglutinative ability of the two sera was manifested. Although these organisms have several characters in common, and particularly the serological reactions, they constitute two separate and distinct types, each bearing a specific relationship to the disease with which it has been associated, namely, either bacillary white diarrhœa or fowl typhoid. Taylor (5) concludes from his studies on fowl typhoid that the lesions produced in fowls which are infected with *Bact. sanguinarium* resemble in many respects those produced by *Bact. pullorum*, but, although there is a still closer resemblance in the biological characters of the two organisms, there is enough difference to warrant the conclusion that they are distinctly different diseases. Ward and Gallagher (6), studying forty-seven birds for comparison of agglutination and intradermal tests on naturally infected birds, report the absolute failure of each test as judged by the other test and by an autopsy, findings being similar in amount. Field tests on two hundred and thirty-one birds made simultaneously with the agglutination test at thirty-eight hours failed to detect one case reported positive to the other test.

Pfeiler and Rehse (7) present the clearest description of an epidemic in fowls due to the fowl typhoid bacillus. The fermentative reaction showed the organism to be similar to the human typhoid bacillus. According to Goldberg (8) the principal differences between the strains of *Bact. pullorum* and *Bact. sanguinarium* studied lie in the fact that *Bact. pullorum* produces gas in various carbohydrates while *Bact. sanguinarium* lacks this power in any of the carbohydrates he used, which included sugar-free media containing dextrose, lactose, saccharose, mannite, dextrine, inuline, galactose, levulose, raffinose, amygdalin, arabinose, adonite, dulcite, xylose, salicin, isodulcite, mannose, starch, glycerine, erythrol. The difference in gas production, as well as in their actions on milk, maltose, dulcite, dextrine, and isodulcite seems to indicate that these two organisms are distinct species of bacteria.

Hadley (1) concludes from his studies on the colon-typhoid intermediates that in carbohydrate media used known types of *Bact. pullorum*, *B. gallinarum*, *B. avisepticus*, *B. paratyphosus* A and B, manifest definite fermentative differences which justify regarding them as distinct species. Since paratyphoid A does not ferment xylose, a close relationship is shown between the types from poultry (pullorum and gallinarum) and paratyphoid B. The data presented indicate that pullorum is much less active than gallinarum on xylose. Aside from gas production there is a closer fermentative relation between *B. gallinarum* and the paratyphoids than between *Bact. pullorum* and the paratyphoids; this is due to the fact that pullorum is maltose-dextrine-dulcite negative. Hadley also finds that all the maltose-dextrine-dulcite negative strains isolated from chicks have been aerogenic, while all of the maltose-dextrine-dulcite negative strains isolated from adult birds were anaerogenic. The author has been able to isolate from the eggs of fowls experiencing infections with the maltose-dextrine-dulcite negative anaerogenic strains both aerogenic and anaerogenic forms. The gas production may vary quantitatively within wide limits. The writer has found that no one of the many original aerogenic pullorum strains, cultivated for years in artificial media, has lost its aerogenic power when placed under favorable conditions for growth; and none (either pullorum or gallinarum) that originally lacked this power ever attained it. According to these data one may conclude that if a strain, possessing otherwise the characteristics of pullorum or of gallinarum, is aerogenic it is not *B. gallinarum*, while if it is anaerogenic it may be either *Bact. pullorum* B or *B. gallinarum*. This indicates that it is necessary to make use of the maltose-dextrine-dulcite fermentation tests only when the strain in question is anaerogenic. In another paper (9) this same author concludes from his data that gas production by *Bact. pullorum* may depend upon whether the cultures are grown in glucose extract or glucose infusion broth. Propagating cultures for many years on artificial media does not cause them to lose their gas-producing ability. *Bact. pullorum* isolated from epidemics of bacillary white diarrhœa in young chicks or from infected eggs is aerogenic; there exist also anaerogenic strains which, in all the cases in which they have been observed, have been isolated from adult fowls experiencing acute or subacute infections simulating fowl typhoid in both clinical symptoms and pathological alterations of tissues. Therefore the writer proposes tentatively to postulate for *Bact. pullorum:* (1) *Bact. pullorum* A, aerogenic; and *Bact. pullorum* B, anaerogenic, pathogenic for adult stock only.

Hadley (10) suggests that *Bact. pullorum* appears to stand as a borderline group in the colon-typhoid intermediates, separating the actual paratyphoids from the actual paracolons; and further suggests that, in order to facilitate bringing about some degree of order in the group of colon-typhoid intermediates, gas-forming strains be referred to the paracolon group which should be revived; and that anaerogenic forms only be referred to the paratyphoid group, in which *B. gallinarum* (Klein) might stand as the type species.

Rettger and Koser (4) present data which indicate that dextrine, maltose and dulcite are attacked by *Bact. sanguinarium* with the production of acid but no gas. *Bact. pullorum* produces, on the other hand, no visible change of media containing these agents except slight alkali production. *Bact. pullorum* acts upon dextrose and mannite with evolution of appreciable amounts of gas, while *Bact. sanguinarium*, whether recently isolated or artificially cultivated for many years, does not produce gas in any of the carbohydrate media. Prolonged cultivation of *Bact. pullorum* in the laboratory does not cause this organism to lose its power of producing gas in dextrose and mannite broth. These authors conclude that *Bact. pullorum* manifests itself only as the cause of natural epidemic infection in young chicks. They further maintain that *Bact. sanguinarium* attacks fowls of different ages, and is of relatively little, if indeed any, significance as the cause of epidemic disease in very young chicks.

Mulsow (11) concludes from his studies that *B. avisepticus* may generally be distinguished from *Bact. sanguinarium* by its action in milk, indol production, fermentation of carbohydrates, agglutination reaction and pathogenesis. *Bact. pullorum* and *Bact. sanguinarium* do not produce indol, generally form hydrogen sulphid in lead acetate medium, and produce a temporary acidity in milk, but later alkalinity. As regards fermentation, *Bact. pullorum* produces acid and generally gas in the same carbohydrates, and in addition produces acid in dulcite and maltose. According to this author, *Bact. pullorum* may be distinguished from *Bact. sanguinarium* by the inability of the former to ferment dulcite, while the latter ferments this carbohydrate. *Bact. sanguinarium* generally produces acid promptly in maltose, and does not produce gas in any of the carbohydrates. Rhamnose is fermented promptly by *Bact. pullorum*, while *Bact. sanguinarium* produces acid only after forty-eight hours' incubation. It appears that there are sufficient differences, reported in this paper by Mulsow, between *Bact. sanguinarium* and *Bact. pullorum* to regard these as separate types.

Krumwiede and Kohn (12) report results which indicate that the essential characteristic of the paratyphoid-enteritidis group is the ability of its members to produce acid from rhamnose, differentiating both the aerogenic and anaerogenic members from *B. typhosus*. They point out that, without due regard to low and latent avidity for carbohydrates in relation to variability and practical differentiation, erroneous differential significance might easily be given to variation even among members of the fixed groups.

Experimental.

In the experiments presented, a study has been made of 112 different strains of *Bact. pullorum* isolated from diseased materials from poultry plants in various parts of Massachusetts, to determine, if possible, biochemical and cultural details which are constant enough to warrant their recommendation as a part of the procedure in diagnosis. The following organisms, listed in Table 1, have been isolated from cases of chick disease, clinically white diarrhœa, and these conformed morphologically, biochemically and serologically to this group of organisms. It was further decided to study the uniformity of these 112 cultures biochemically and serologically, and to determine how many of them gave reactions which were similar to the reactions of its close relative, the fowl typhoid organism (*Bact. sanguinarium*). The cultures of *Bact. sanguinarium* were isolated from birds sent here for diagnosis, and the Smith, Cornell and Gage strains. There were five strains in this list. The two other than the three mentioned appeared typical of sanguinarium, were isolated during the early part of 1920, and designated the Humphrey and Massachusetts strains, respectively.

The following table lists the cultures of *Bact. pullorum* isolated and studied during the course of this work: —

TABLE 1. — *Strains of Bacterium Pullorum studied in this Investigation.*

Bacterium Pullorum.	Source of Culture.	When Isolated and Studied.
Strain No. 1 . . .	M. A. C. Amherst, Mass. Isolated March, 1914, from M. A. C. chick. Used in summer of 1914 as Strain A.	March, 1914
Strain No. 2 . . .	Experimental material from this laboratory. From unabsorbed yolk of chick inoculated summer of 1913 with S_3 (S_3 from Cutler egg). Used in summer of 1914 as Strain B.	
Strain No. 3 . . .	Isolated from material sent to laboratory. Used as Strain C in summer of 1914.	
Strain No. 4 . . .	Bridgewater, Mass. Isolated from Cutler chick. Used as S_2 in 1913. Used as Strain D in 1914.	
Strain No. 5 . . .	Maryland. Used at Maryland Experiment Station in 1911.	
Strain No. 6 . . .	Sterling, Mass. Isolated 1914. Trask Strain. Used as Strain F in summer of 1914.	May 1, 1914
Strain No. 7 . . .	Holliston, Mass. Isolated from chicks sent by C. E. Cristman, Silverwood Farm, Holliston, Mass. These chicks were bought of A. B. H. Arnold, Holliston, Mass.	Feb. 20, 1915
Strain No. 8 . . .	M. A. C. Amherst, Mass. No. 231 (2703) from unabsorbed yolk (chick).	Mar. 31, 1915
Strain No. 9 . . .	Holliston, Mass. Isolated from unabsorbed yolk of chick. Isolated from liver of chick.	
Strain No. 10 . . .	Northborough, Mass. Isolated from liver of chick .	Apr. 1, 1915
Strain No. 11 . . .	Franklin, Mass. 11-1 isolated from unabsorbed yolk of chick No. 2; 11-2 isolated from liver of chick No. 5.	
Strain No. 12 . . .	North Hadley, Mass. 12-1 from unabsorbed yolk of chick No. 1; 12-2 from unabsorbed yolk of chick No. 4; 12-3 from unabsorbed yolk of chick No. 9.	Apr. 5, 1915
Strain No. 13 . . .	Kingston, Mass. Isolated from unabsorbed yolk of chick No. 2.	Apr. 5, 1915
Strain No. 14 . . .	Center Marshfield, Mass. Isolated from unabsorbed yolk of chick No. 4.	Apr. 6, 1915
Strain No. 15 . . .	Brookline, Mass. Isolated from unabsorbed yolk of chick No. 1.	Apr. 7, 1915
Strain No. 16 . . .	Amherst, Mass. Isolated from liver of chick No. 1; 16-2 isolated from unabsorbed yolk of chick No. 1; 16-3 isolated from liver of chick No. 2.	Apr. 12, 1915
Strain No. 17 . . .	Southborough, Mass. 17-1 isolated from liver of chick No. 1; 17-2 isolated from heart of chick No. 2; 17-3 isolated from heart of chick No. 3; 17-4 isolated from unabsorbed yolk of chick No. 4; 17-5 isolated from unabsorbed yolk of chick No. 5; 17-6 isolated from unabsorbed yolk of chick No. 6.	Apr. 16, 1915
Strain No. 18 . . .	Littleton, Mass. 18-1 isolated from heart of chick No. 1; 18-2 isolated from liver of chick No. 1.	Apr. 17, 1915
Strain No. 19 . . .	Andover, Mass. Isolated from unabsorbed yolk of chick No. 1.	Apr. 22, 1915

TABLE 1.—*Strains of Bacterium Pullorum studied in this Investigation*—Continued.

Bacterium Pullorum.	Source of Culture.	When Isolated and Studied.
Strain No. 20 . . .	Westborough, Mass. Isolated from unabsorbed yolk of chick No. 2.	Apr. 23, 1915
Strain No. 21 . . .	Amherst, Mass. Chicks hatched from eggs bought at Hickory Farm, Ludlow, Mass. 21-1 isolated from heart of chick; 21-2 isolated from liver of chick.	May 15, 1915
Strain No. 22 . . .	Shrewsbury, Mass. Isolated from unabsorbed yolk of chick No. 1.	May 13, 1915
Strain No. 23 . . .	Natick, Mass. Isolated from liver of chick No. 1 .	May 14, 1915
Strain No. 24 . . .	Lowell, Mass. 24-1 isolated from unabsorbed yolk of chick No. 1; 24-2 isolated from unabsorbed yolk of chick No. 2.	May 15, 1915
Strain No. 25 . . .	South Hadley, Mass. 25-1 isolated from liver of chick No. 1; 25-2 isolated from unabsorbed yolk of chick No. 2.	June 2, 1915
Strain No. 26 . . .	Amherst, Mass. 26-1 isolated from liver of chick No. 1; 26-2 isolated from liver of chick No. 2.	June 2, 1915
Strain No. 27 . . .	Dedham, Mass. 27-1 isolated from liver of chick No. 1; 27-2 isolated from liver of chick No. 2.	June 2, 1915
Strain No. 28 . . .	Belchertown, Mass. Isolated from liver and unabsorbed yolk of chick.	May 2, 1916
Strain No. 29 . . .	Nobscot, Mass. 29-1 isolated from liver and unabsorbed yolk of chick; 29-2 isolated from liver and unabsorbed yolk of chick; 29-3 isolated from liver and unabsorbed yolk of chick; 29-4 isolated from liver and unabsorbed yolk of chick.	July 28, 1916
Strain No. 30 . . .	Concord, Mass. 30-1 isolated from liver and unabsorbed yolk of chick; 30-2 isolated from liver and unabsorbed yolk of chick; 30-3 isolated from liver and unabsorbed yolk of chick; 30-4 isolated from liver and unabsorbed yolk of chick; 30-5 isolated from liver and unabsorbed yolk of chick; 30-6 isolated from liver and unabsorbed yolk of chick.	Mar. 24, 1916
Strain No. 31 . . .	Holliston, Mass. 31-1 isolated from unabsorbed yolk of chick; 31-2 isolated from liver of chick; 31-3 isolated from unabsorbed yolk of chick.	May 2, 1917
Strain No. 32 . . .	Shrewsbury, Mass. Isolated from unabsorbed yolk of chick.	Feb. 28, 1917
Strain No. 33 . . .	Morrisville, N. Y. 33-1 isolated from unabsorbed yolk of chick; 33-2 isolated from unabsorbed yolk of chick.	Mar. 28, 1917
Strain No. 34 . . .	Egypt, Mass. Isolated from unabsorbed yolk of chick.	Mar. 16, 1917
Strain No. 35 . . .	Plainville, Mass. Isolated from unabsorbed yolk of chick.	Apr. 15, 1917
Strain No. 36 . . .	Fitchburg, Mass. 36-1 isolated from liver of chick; 36-2 isolated from liver of chick.	Apr. 13, 1917
Strain No. 37 . . .	Lunenburg, Mass. Isolated from liver of chick; 37-2 isolated from liver of chick.	Apr. 13, 1917
Strain No. 38 . . .	Sutton, Mass. 38-1 isolated from unabsorbed yolk of chick; 38-2 isolated from liver of chick.	Apr. 13, 1917
Strain No. 39 . . .	Southborough, Mass. Isolated from liver of chick	Apr. 16, 1917
Strain No. 40 . . .	Cohasset, Mass. Isolated from unabsorbed yolk of chick.	Apr. 16, 1917
Strain No. 41 . . .	Amherst, Mass. 41-1 isolated from unabsorbed yolk of chick; 41-2 isolated from unabsorbed yolk of chick; 41-3 isolated from unabsorbed yolk of chick; 41-4 isolated from unabsorbed yolk of chick.	Apr. 15, 1917
Strain No. 42 . . .	Shirley, Mass. 42-1 isolated from unabsorbed yolk of chick; 48-2 isolated from unabsorbed yolk of chick.	Apr. 18, 1917
Strain No. 43 . . .	Middleton, Mass. 43-1 isolated from ovary of chick; 43-2 isolated from ovary of chick.	Apr. 21, 1917
Strain No. 44 . . .	Spencer, Mass. Isolated from liver of chick . .	May 2, 1917
Strain No. 45 . . .	Greenfield, Mass. 45-1 isolated from liver of chick; 45-2 isolated from liver of chick.	May 3, 1917
Strain No. 46 . . .	Winchendon, Mass. 46-1 isolated from liver of chick; 46-2 isolated from liver of chick.	May 8, 1917

TABLE 1. — *Strains of Bacterium Pullorum studied in this Investigation* — Continued.

Bacterium Pullorum.	Source of Culture.	When Isloated and Studied.
Strain No. 47 . . .	Pittsfield, Mass. Isolated from liver of chick . .	May 7, 1917
Strain No. 48 . . .	Peabody, Mass. 48-1 isolated from unabsorbed yolk of chick; 48-2 isolated from unabsorbed yolk of chick.	May 24, 1917
Strain No. 49 . . .	Weymouth, Mass. 49-1 isolated from unabsorbed yolk of chick; 49-2 isolated from unabsorbed yolk of chick; 49-3 isolated from unabsorbed yolk of chick; 49-4 isolated from unabsorbed yolk of chick.	Apr. 10, 1917
Strain No. 50 . . .	Westfield, Mass. Isolated from unabsorbed yolk of chick.	May 24, 1917
Strain No. 51 . . .	Methuen, Mass. Isolated from liver of chick . .	Mar. 7, 1920
Strain No. 52 . . .	Methuen, Mass. Isolated from unabsorbed yolk of chick.	Mar. 7, 1920
Strain No. 53 . . .	Methuen, Mass. Isolated from unabsorbed yolk of chick.	Mar. 7, 1920
Strain No. 54 . . .	Methuen, Mass. Isolated from heart of chick . .	Mar. 7, 1920
Strain No. 55 . . .	Webster, Mass. Isolated from unabsorbed yolk of chick.	Mar. 15, 1920
Strain No. 56 . . .	Webster, Mass. Isolated from heart of chick . .	Mar. 15, 1920
Strain No. 57 . . .	Webster, Mass. Isolated from unabsorbed yolk of chick.	Mar. 15, 1920
Strain No. 58 . . .	Andover, Mass. Isolated from unabsorbed yolk of chick.	Mar. 19, 1920
Strain No. 59 . . .	Andover, Mass. Isolated from liver of chick . .	Mar. 19, 1920
Strain No. 60 . . .	Natick, Mass. Isolated from unabsorbed yolk of chick.	Mar. 19, 1920
Strain No. 61 . . .	Natick, Mass. Isolated from unabsorbed yolk of chick.	Mar. 19, 1920
Strain No. 62 . . .	Natick, Mass. Isolated from heart of chick . .	Mar. 19, 1920
Strain No. 63 . . .	Natick, Mass. Isolated from unabsorbed yolk of chick.	Mar. 19, 1920
Strain No. 64 . . .	Hubbardston, Mass. Isolated from liver of chick .	Mar. 23, 1920
Strain No. 65 . . .	Hubbardston, Mass. Isolated from liver of chick .	Mar. 23, 1920
Strain No. 66 . . .	Hubbardston, Mass. Isolated from unabsorbed yolk of chick.	Mar. 23, 1920
Strain No. 67 . . .	Hubbardston, Mass. Isolated from liver of chick .	Mar. 23, 1920
Strain No. 68 . . .	Lexington, Mass. Isolated from heart of chick .	Apr. 8, 1920
Strain No. 69 . . .	Lexington, Mass. Isolated from liver of chick .	Apr. 8, 1920
Strain No. 70 . . .	Lexington, Mass. Isolated from liver of chick .	Apr. 8, 1920
Strain No. 71 . . .	Lexington, Mass. Isolated from heart of chick .	Apr. 8, 1920
Strain No. 72 . . .	Longmeadow, Mass. Isolated from liver of chick .	Apr. 3, 1920
Strain No. 73 . . .	Plymouth, Mass. Isolated from liver of chick .	Apr. 3, 1920
Strain No. 74 . . .	Essex, Mass. Isolated from heart of chick . .	Apr. 9, 1920
Strain No. 75 . . .	Worcester, Mass. Isolated from unabsorbed yolk of chick.	Apr. 9, 1920
Strain No. 76 . . .	Worcester, Mass. Isolated from unabsorbed yolk of chick.	Apr. 9, 1920
Strain No. 77 . . .	Belchertown, Mass. Isolated from unabsorbed yolk of chick.	Apr. 9, 1920
Strain No. 78 . . .	Bridgewater, Mass. Isolated from liver of chick .	Apr. 12, 1920
Strain No. 79 . . .	Bridgewater, Mass. Isolated from unabsorbed yolk of chick.	Apr. 12, 1920
Strain No. 80 . . .	Wellesley, Mass. Isolated from unabsorbed yolk of chick.	Apr. 14, 1920
Strain No. 81 . . .	East Braintree, Mass. Isolated from liver of chick	Apr. 14, 1920

TABLE 1.—*Strains of Bacterium Pullorum studied in this Investigation*—Concluded.

Bacterium Pullorum.	Source of Culture.	When Isolated and Studied.
Strain No. 82 . . .	M. A. C. Amherst, Mass. Isolated from liver of chick.	Apr. 20, 1920
Strain No. 83 . . .	M. A. C. Amherst, Mass. Isolated from unabsorbed yolk of chick.	Apr. 20, 1920
Strain No. 84 . . .	M. A. C. Amherst, Mass. Isolated from unabsorbed yolk of chick.	Apr. 20, 1920
Strain No. 85 . . .	Chester, Mass. Isolated from unabsorbed yolk of chick.	Apr. 21, 1920
Strain No. 86 . . .	Chester, Mass. Isolated from liver of chick . .	Apr. 21, 1920
Strain No. 87 . . .	Chester, Mass. Isolated from liver of chick . .	Apr. 21, 1920
Strain No. 88 . . .	Boston, Mass. Isolated from liver of chick . .	Apr. 21, 1920
Strain No. 89 . . .	Leominster, Mass. Isolated from liver of chick .	Apr. 21, 1920
Strain No. 90 . . .	Medway, Mass. Isolated from liver of chick . .	Apr. 27, 1920
Strain No. 91 . . .	Medway, Mass. Isolated from liver of chick . .	Apr. 27, 1920
Strain No. 92 . . .	Wakefield, Mass. Isolated from liver of chick . .	Apr. 27, 1920
Strain No. 93 . . .	Wakefield, Mass. Isolated from liver of chick .	Apr. 27, 1920
Strain No. 94 . . .	M. A. C. Amherst, Mass. Isolated from unabsorbed yolk of chick.	Apr. 27, 1920
Strain No. 95 . . .	M. A. C. Amherst, Mass. Isolated from liver of chick.	Apr. 27, 1920
Strain No. 96 . . .	Littleton, Mass. Isolated from heart of chick . .	Apr. 30, 1920
Strain No. 97 . . .	Bedford, Mass. Isolated from liver of chick . .	Apr. 30, 1920
Strain No. 98 . . .	Bedford, Mass. Isolated from liver of chick . .	Apr. 30, 1920
Strain No. 99 . . .	Worcester, Mass. Isolated from liver of chick . .	May 4, 1920
Strain No. 100 . . .	Worcester, Mass. Isolated from liver of chick . .	May 4, 1920
Strain No. 101 . . .	West Acton, Mass. Isolated from liver of chick .	May 7, 1920
Strain No. 102 . . .	West Acton, Mass. Isolated from liver of chick .	May 7, 1920
Strain No. 103 . . .	Woonsocket, R. I. Isolated from liver of chick .	May 11, 1920
Strain No. 104 . . .	Woonsocket, R. I. Isolated from liver of chick .	May 11, 1920
Strain No. 105 . . .	Woonsocket, R. I. Isolated from liver of chick .	May 11, 1920
Strain No. 106 . . .	Belchertown, Mass. Isolated from unabsorbed yolk of chick.	May 14, 1920
Strain No. 107 . . .	Segreganset, Mass. Isolated from liver of chick .	May 18, 1920
Strain No. 108 . . .	Waltham, Mass. Isolated from liver of chick . .	May 21, 1920
Strain No. 109 . . .	Charlemont, Mass. Isolated from unabsorbed yolk of chick.	May 28, 1920
Strain No. 110 . . .	Hampton Falls, N. H. Isolated from liver of chick	May 29, 1920
Strain No. 111 . . .	Southwick, Mass. Isolated from liver of chick .	May 19, 1920
Strain No. 112 . . .	Hudson, Mass. Isolated from unabsorbed yolk of chick.	June 3, 1920

Change of Reaction in Carbohydrate Media by the 112 Strains of Bacterium Pullorum.

The cultures of *Bact. pullorum* were grown in test tubes of uniform length and caliber and in standard beef extract bouillon containing 1 per cent of the carbohydrate. These results were somewhat lower than those obtained by Goldberg (8), who found by using infusion broth that the percentage was higher. According to Hadley (10), on an average 0.7 per cent more acid is produced in sugar-infusion broth than in sugar-extract broth. Two drops of a bouillon suspension of each strain were used as the inoculum for a test, triplicate titrations made, and the average percentage acidity noted at the end of the fifth day. It appeared from our work in relation to time of acid production that the maximum occurred between the fifth and tenth day. Therefore the tables and curves represent the amount of acid at the end of a five-day period, at 37.5° C., expressed in percentage normal acid. All titrations were made in the cold, using $\frac{N}{20}$ NaOH and $\frac{N}{20}$ HCl and phenolphthalein as the indicator. Gas production was determined in dextrose, galactose, mannite, levulose, arabinose, salicin, mannose, xylose, adonite, erythrol, saccharose, dulcite, dextrine, lactose, raffinose, inulin, maltose and glycerine. Durham double-barreled fermentation tubes were employed, and the percentage of gas in the inner tube read off on the Frost gasometer chart at the end of five days' incubation at 37.5° C.

Dextrose. — This sugar was fermented by all the 112 strains. The lowest amount of acidity was 0.6 per cent and the highest 1.8 per cent, the mean of 108 determinations being 1.4 per cent acid. Gas was produced in this carbohydrate by all strains, ranging in quantity from a bubble to 55 per cent, the average for all the 112 strains being 20 per cent.

Mannite. — The acid production in mannite was greater than in dextrose and much more variable. After five days' growth the 112 strains had produced an average of 1.0 per cent acidity. The exceptions to this average were strains 23, 46 and 72 which produced 2.0 per cent, 2.2 per cent, and 1.7 per cent, respectively. Gas was produced by all strains, ranging in quantity from 20 to 50 per cent, with an average for the 112 strains of 30 per cent.

Galactose. — This sugar was fermented by all strains, being very much like mannite and dextrose. The acidity ranged from 0.1 to 2.1 per cent, the average for all cultures being 0.9 per cent. There were four exceptions which make a wide variation in the curve, — strains 29, 33, 42 and 49, which produced 0.1, 1.9, 2.0 and 2.1 per cent, respectively.

Levulose. — This sugar was fermented easily by all strains of *Bact. pullorum*, and the changes in reaction here correspond with those in dextrose, mannite and galactose, the acidity ranging from 0.2 to 2.0 per cent, the average for the 112 strains being 0.9 per cent. The exceptions were strains 63, 72 and 73, which produced 2.0, 1.9 and 1.5 per cent acidity, respectively.

Arabinose. — All strains fermented this carbohydrate, the acidity ranging from 0.5 to 1.0 per cent, with an average for the 112 strains of 0.7 per cent. This carbohydrate was fermented in a very variable manner.

Salicin. — None of the 112 strains fermented salicin. On the fifth day there was marked alkaline reaction in some strains. The average acidity for the 112 strains was 0.1 per cent.

Mannose. — This sugar was fermented by all the strains. The minimum acidity by any strain was 0.6 and the maximum 1.3 per cent. The average for the 112 strains was 0.9 per cent acid.

Xylose. — This sugar was fermented by all the strains, but none produced marked quantities of acid. The minimum produced by any strain was 0.1 and the maximum 0.4 per cent, with a mean of 0.25 per cent for the 112 strains. Therefore it may be said that these pullorum strains are not strongly xylose positive.

Adonite. — For the most part the initial acidity was not greatly changed. The minimum figure observed was an alkalinity of 0.1 per cent and the maximum an acidity of 0.1 per cent. As a group these strains were adonite-negative, the curve of results from the 112 strains running close to the line of initial acidity.

Erythrol. — This carbohydrate was not fermented significantly by any of the cultures of *Bact. pullorum* studied. All strains gave a reduction of the initial acidity. The acidity ranged from a minimum of —0.4 per cent to a figure which represented no change from original acidity. Therefore these 112 strains are erythrol negative.

Saccharose. — There was no appreciable amount of acid produced in this carbohydrate. The minimum reading was —0.2 per cent and a few readings showed no change from the initial acidity. The average acidity determination for the 112 strains was —0.2 per cent. There were two exceptions, strains 67 and 84, which showed a determination of —0.4 and —0.5 per cent for acidity. Therefore in saccharose there is no acid formed by *Bact. pullorum.*

Dulcite. — All the 112 strains of *Bact. pullorum* showed a marked reduction of acidity. A few strains did not change the initial acidity, the range being between no change of acidity and —0.4 per cent. There were three exceptions, however, cultures 32, 46 and 47, which produced the following results: —0.6, —0.5 and —0.5 per cent, respectively. Therefore it may be said that the results from these determinations indicate that *Bact. pullorum* is dulcite negative.

Dextrine. — The initial acidity was readily reduced by all strains studied. The readings ranged from no change in acidity to —0.3 per cent. There were no exceptions, all cultures demonstrating this reduction.

Lactose. — The initial acidity was reduced by all strains. The readings ranged from no change in acidity to —0.4 per cent, the mean reading being —0.12 per cent. *Bact. pullorum* may be considered, consequently, lactose-negative as regards acid production. Two strains, 93 and 109, were unusually prompt in this particular. Both strains gave a reading of —0.4.

Raffinose. — The acidity was reduced by all the pullorum strains. The average reading for the 112 cultures was —0.2 per cent. Strain 48 was capable of greater alkaline production than the others, giving a result of —0.5 per cent.

Inulin. — All strains of *Bact. pullorum* were negative in this carbohydrate, the mean reading being —0.19 per cent. There was a prompt reduction in initial acidity, only one culture of the 112 showing no change in the initial acidity.

Maltose. — None of the 112 strains produced any acid. The change was usually marked in all tubes on the fifth day. There was an average reduction of acidity of —0.18 per cent.

Glycerine. — None of the 112 strains produced any acid in glycerine. The determination on the fifth day showed a reduction in the final acidity, averaging —0.1 per cent.

Conclusions from the Fermentation Tests.

From the tests reported concerning the fermentation of the 112 strains of *Bact. pullorum*, it appears that this organism is positive in dextrose, galactose, mannose, mannite, levulose, xylose and arabinose; and negative in glycerine, maltose, adonite, dulcite, lactose, dextrine, saccharose, inulin, erythrol and raffinose. In salicin there is a slight indication of fermentation, at least a slight acidity in a large percentage of the strains. All strains of this organism studied showed a marked tendency to produce gas in

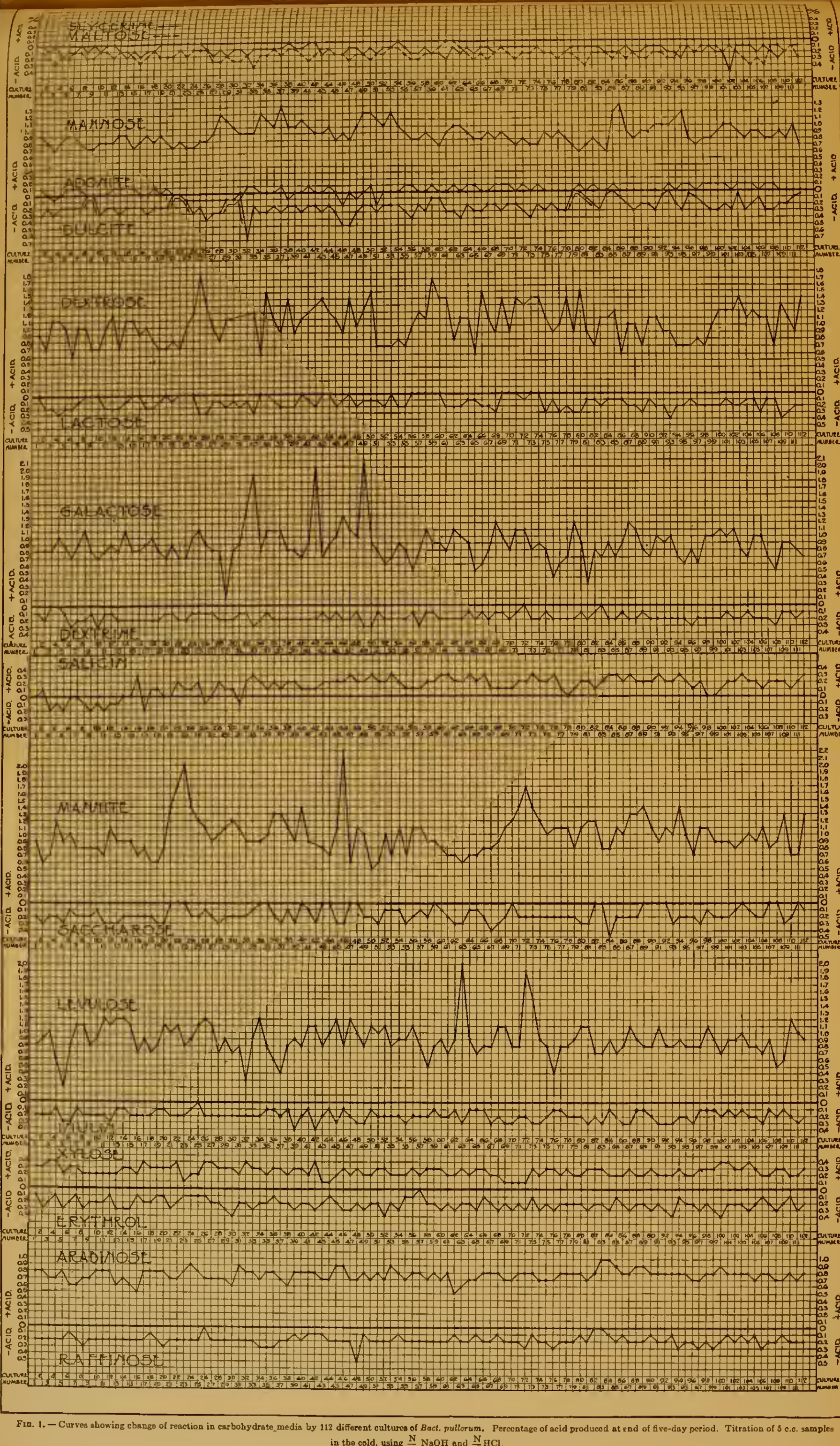

FIG. 1.—Curves showing change of reaction in carbohydrate media by 112 different cultures of *Bact. pullorum*. Percentage of acid produced at end of five-day period. Titration of 5 c.c. samples in the cold, using $\frac{N}{20}$ NaOH and $\frac{N}{20}$ HCl.

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dextrose. This aerogenic property of the pullorum strains is persistent. Cultures of pullorum carried for fourteen months in France during the war, and kept under adverse conditions, when planted again under favorable conditions regained their aerogenic properties, and the activities in this direction were as marked as in the original cultures. The 112 strains of *Bact. pullorum* studied, even after being transferred eighteen times, still retain active gas production in dextrose and mannite. In one exception, culture No. 44, there has never developed more than a bubble of gas in the dextrose. This is recorded in the table in the dextrose column as B, meaning bubble. All strains are methyl red negative. Therefore from previous morphological and cultural tests, linked with these biochemical findings, it may be concluded that the organism classed to-day as *Bact. pullorum* A should be a slender, non-motile, non-liquefying, gram-negative bacillus. It does not coagulate or peptonize milk. It produces gas in dextrose and mannite, forms H_2S in lead acetate medium, does not produce indol, and does not reduce nitrates.

Fermentation Tests with Bacterium Sanguinarium.

Dextrose. — This sugar was fermented by all the five strains, 0.8 per cent being the highest amount and 0.7 per cent the lowest, the mean being 0.7 per cent.

Mannite. — All cultures of *Bact. sanguinarium* produced about the same quantity of acidity, 0.8 per cent.

Galactose. — Fermented by *Bact. sanguinarium*, the percentage acidity being 0.7, 0.7, 0.6, 0.8 and 0.7 per cent, respectively.

Levulose. — Fermented more variably than galactose, 0.6 per cent being the lowest figure, and 0.9 per cent the highest.

Arabinose. — All strains fermented this carbohydrate, the readings being between 0.6 and 0.8 per cent acid.

Salicin. — Not fermented by the five strains.

Mannose. — This carbohydrate was fermented by *Bact. sanguinarium* about the same as mannite.

Xylose. — Fermented less actively in this carbohydrate, the readings being 0.5, 0.3, 0.2, 0.5 and 0.4 per cent acidity, respectively.

Adonite. — Not appreciably fermented by *Bact. sanguinarium.* The maximum figure obtained was 0.1 per cent acidity.

Erythrol. — Not fermented significantly by any of the five strains of *Bac. sanguinarium.*

Saccharose. — Not fermented by *Bact. sanguinarium.* There was increased alkalinity.

Dulcite. — In this carbohydrate the initial acidity was increased, 0.4 per cent being the maximum amount determined in any of the five cultures.

Dextrine. — There was a marked increase in acidity, four of the five strains of *Bact. sanguinarium* showing 0.6 per cent.

Lactose. — There was no increase in acidity by *Bact. sanguinarium.* There was a marked production of alkalinity.

Raffinose. — There was no increase in acidity in this carbohydrate; the initial acidity was markedly reduced.

Inulin. — There was no increase in acidity in this carbohydrate; the initial acidity was markedly reduced.

Maltose. — Large increase in acid was noted by all strains of *Bact. sanguinarium* in this carbohydrate.

Glycerine. — None of the strains of *Bact. sanguinarium* produced any acid in glycerine. The determination on the fifth day showed a reduction in initial acidity.

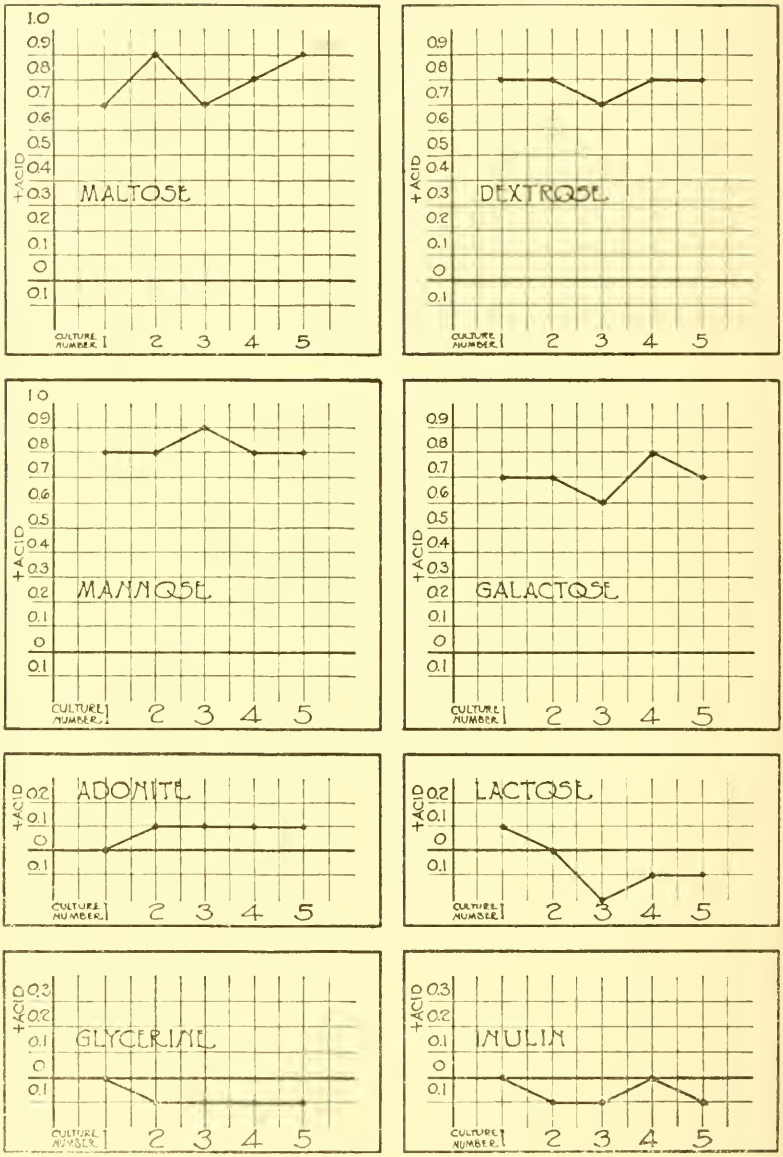

FIG. 2. — Curves showing change of reaction in carbohydrate media by cultures of *Bacterium sanguinarium*. Percentage of acid produced at end of five-day period. Titration of 5 c.c. samples in the cold, using $\frac{N}{20}$ NaOH and $\frac{N}{20}$ HCl.

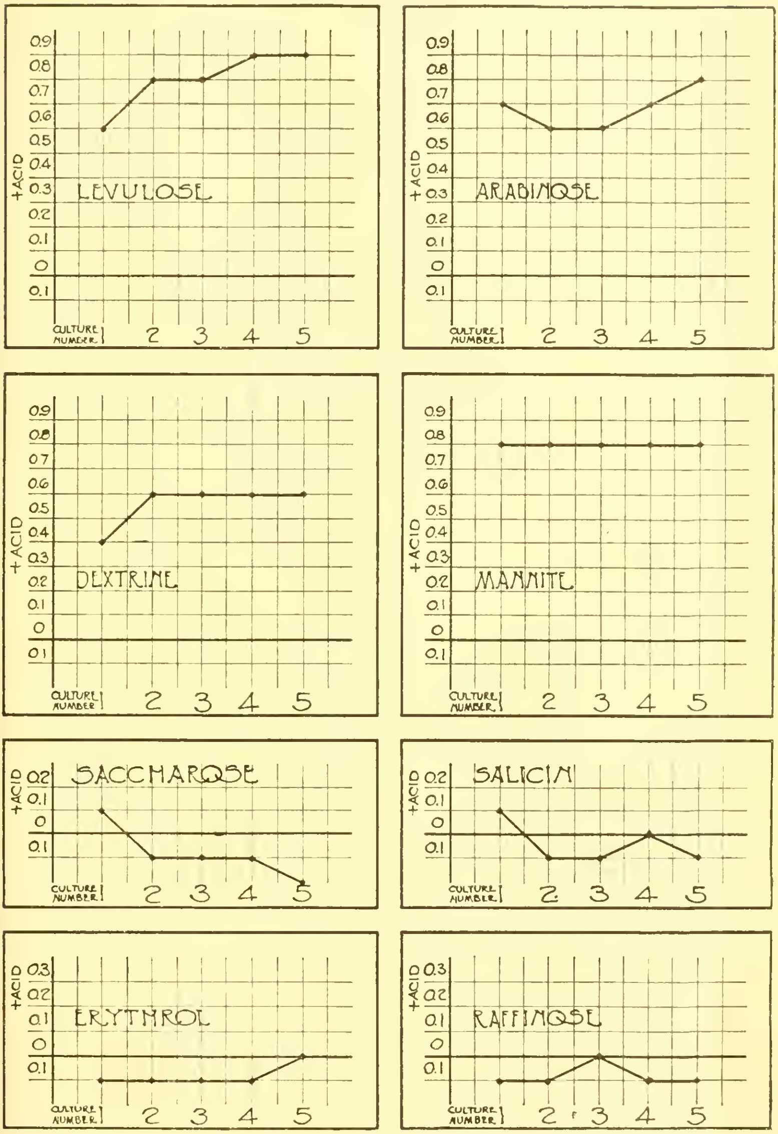

Fig. 2. — Curves showing change of reaction in carbohydrate media by cultures of *Bacterium sanguinarium* — *Continued.*

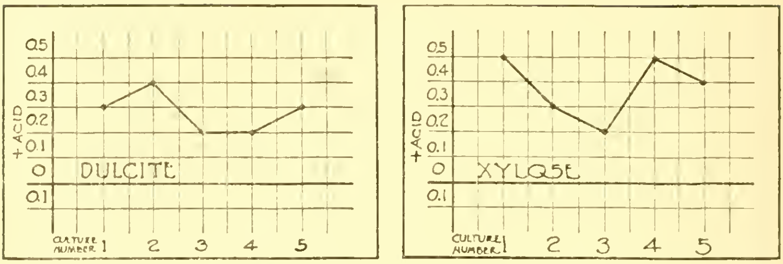

FIG. 2. — Curves showing change of reaction in carbohydrate media by cultures of *Bacterium sanguinarium* — *Concluded.*

TABLE 2. — *Gas Production of the 112 Strains of Bacterium pullorum in Carbohydrate Broth.*

[Percentage of gas in closed arm of fermentation tube.]

Culture Number.	Dextrose.	Mannite.	Galactose.	Levulose.	Arabinose.	Salicin.	Mannose.	Xylose.	Dulcite.	Culture Number.	Dextrose.	Mannite.	Galactose.	Levulose.	Arabinose.	Salicin.	Mannose.	Xylose.	Dulcite.
1	17	20	0	0	0	0	26	0	0	57	20	45	0	0	0	0	25	0	0
2	33	50	0	0	0	0	30	0	0	58	15	30	0	0	0	0	30	0	0
3	37	35	0	B	4	43	30	5	25	59	18	25	0	0	0	0	20	0	0
4	43	30	0	0	0	25	0	0	0	60	17	40	0	0	0	0	20	0	0
5	25	25	0	B	0	0	20	0	0	61	10	25	0	0	0	0	25	0	0
6	30	30	5	0	0	0	20	0	0	62	25	45	5	B	0	0	30	0	0
7	55	25	0	0	0	0	30	0	0	63	18	45	0	0	0	0	22	0	0
8	12	20	0	0	0	0	20	0	0	64	22	40	0	0	0	0	20	0	0
9	15	30	0	0	0	0	30	0	0	65	10	35	0	0	0	0	25	0	0
10	10	25	0	0	0	0	20	0	0	66	12	30	0	0	0	0	30	0	0
11	16	30	0	0	0	0	B	0	0	67	19	25	0	0	0	0	30	0	0
12	16	25	0	0	0	0	B	0	0	68	22	25	0	0	0	0	B	0	0
13	10	25	0	B	0	0	B	0	0	69	23	45	0	0	0	0	20	0	0
14	22	25	0	0	0	0	B	0	0	70	16	35	0	0	0	0	25	0	0
15	10	25	0	0	0	0	25	0	0	71	22	30	0	0	0	0	20	0	0
16	17	30	0	0	0	0	0	0	0	72	17	30	0	0	0	0	30	0	0
17	13	30	0	0	0	0	12	0	0	73	17	30	0	0	0	0	20	0	0
18	14	30	0	0	0	0	15	0	0	74	20	20	0	0	0	0	20	0	0
19	20	30	0	0	0	0	25	0	0	75	17	30	0	0	0	0	20	0	0
20	10	25	0	0	0	0	25	0	0	76	28	30	0	0	0	0	25	0	0
21	20	40	0	0	0	0	22	0	0	77	17	30	0	0	0	0	26	0	0
22	13	30	0	0	0	0	18	0	0	78	18	30	0	0	0	0	20	0	0
23	13	30	0	0	0	0	25	0	0	79	20	25	0	0	0	0	25	0	0

B—Bubble. 0—No gas.

Adonite, erythrol, saccharose, dextrine, lactose, raffinose, inulin, maltose and glycerine produced no gas with any of the cultures.

TABLE 2. — *Gas Production of the 112 Strains of Bacterium Pullorum in Carbohydrate Broth* — Concluded.

Culture Number.	Dextrose.	Mannite.	Galactose.	Levulose.	Arabinose.	Salicin.	Mannose.	Xylose.	Dulcite.	Culture Number.	Dextrose.	Mannite.	Galactose.	Levulose.	Arabinose.	Salicin.	Mannose.	Xylose.	Dulcite.
24 .	17	20	0	0	0	0	5	0	0	80 .	27	40	0	0	0	0	20	0	0
25 .	15	30	10	0	0	0	35	0	0	81 .	20	30	0	0	0	0	25	0	0
26 .	28	30	0	0	0	0	B	0	0	82 .	13	30	0	0	0	0	20	0	0
27 .	23	30	0	0	0	0	25	0	0	83 .	15	25	0	0	0	0	20	0	0
28 .	18	25	0	0	0	0	15	0	0	84 .	27	25	0	0	0	0	25	0	0
29 .	20	45	0	0	0	0	B	0	0	85 .	20	25	0	0	0	0	20	0	0
30 .	10	20	0	0	0	0	B	0	0	86 .	13	25	0	0	0	0	20	0	0
31 .	20	45	0	0	0	0	32	0	0	87 .	15	30	0	0	0	0	25	0	0
32 .	13	40	0	0	0	0	35	0	0	88 .	25	25	0	0	0	0	20	0	0
33 .	30	35	0	0	0	0	15	0	0	89 .	22	30	0	0	0	0	20	0	0
34 .	27	30	0	0	0	0	35	0	0	90 .	20	20	0	0	0	0	25	0	0
35 .	25	25	0	B	0	0	25	0	0	91 .	23	20	0	0	0	0	30	0	0
36 .	27	30	0	0	0	0	25	0	0	92 .	47	45	5	B	0	0	20	0	0
37 .	25	45	0	0	0	0	35	0	0	93 .	10	35	0	0	0	0	25	0	0
38 .	28	35	0	0	0	0	35	0	0	94 .	10	30	0	0	0	0	20	0	0
39 .	25	40	0	0	0	0	0	0	0	95 .	20	25	0	0	0	0	30	0	0
40 .	25	30	0	0	0	0	30	0	0	96 .	25	30	0	0	0	0	0	0	0
41 .	29	35	0	0	0	0	18	0	0	97 .	10	25	0	0	0	0	0	0	0
42 .	45	45	10	10	0	0	5	0	0	98 .	23	20	0	0	0	0	20	0	0
43 .	8	30	0	0	0	0	15	0	0	99 .	27	50	0	0	0	0	25	0	0
44 .	B	20	0	0	0	0	28	0	0	100 .	17	35	0	0	0	0	15	0	0
45 .	20	30	0	0	0	0	22	0	0	101 .	13	30	0	0	0	0	10	0	0
46 .	48	25	15	0	0	0	35	0	0	102 .	17	25	0	0	0	0	25	0	0
47 .	5	25	0	0	0	0	0	0	0	103 .	40	30	10	B	0	0	30	0	0
48 .	27	30	0	0	0	0	0	0	0	104 .	33	25	0	0	0	0	20	0	0
49 .	10	0	0	0	0	0	0	0	0	105 .	30	20	5	B	0	0	20	0	0
50 .	20	50	0	0	0	0	30	0	0	106 .	28	30	0	0	0	0	25	0	0
51 .	17	30	0	0	0	0	B	0	0	107 .	25	25	0	0	0	0	25	0	0
52 .	30	25	0	0	0	0	B	0	0	108 .	17	30	0	0	0	0	30	0	0
53 .	12	25	0	0	0	0	25	0	0	109 .	20	25	0	0	0	0	20	0	0
54 .	32	30	10	0	0	0	B	0	0	110 .	28	20	0	0	0	0	20	0	0
55 .	17	20	0	0	0	0	40	0	0	111 .	10	25	0	0	0	0	25	0	0
56 .	22	30	0	0	0	0	25	0	0	112 .	22	25	0	0	0	0	25	0	0

B = Bubble. 0 = No gas.

Adonite, erythrol, saccharose, dextrine, lactose, raffinose, inulin, maltose and glycerine produced no gas with any of the cultures.

TABLE 3.—*Summary of Biochemical Data as Regards Fermentation of the 112 Strains of Bacterium Pullorum.*

[Acid[1] and gas[2] production.]

Culture	Dextrose		Mannite		Galactose		Levulose		Arabinose		Salicin		Mannose		Xylose		Adonite		Erythrol		Saccharose		Dulcite		Dextrine		Lactose		Raffinose		Inulin		Maltose		Glycerine	
	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas
1	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	O	–
2	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	+	+	+	+	+	–	+	B	+	+	–	+	–	+	+	+	–	–	–	–	–	–	–	+	O	–	–	–	–	–	–	–	–	–	O	–
4	+	+	+	+	+	–	+	–	+	–	–	+	–	–	+	–	O	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–	–	–
5	+	+	+	+	+	–	+	B	+	–	–	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	+	+	+	+	+	+	+	–	+	–	O	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
8	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	O	–	–	–	–	–	O	–	–	–	O	–	–	–	–	–	–	–	–	–
9	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	O	–	–	–	–	–	O	–	–	–	O	–	–	–	–	–	–	–	O	–
10	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
11	+	+	+	+	+	–	+	–	+	–	–	–	–	B	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
12	+	+	+	+	+	–	+	–	+	–	–	–	–	B	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
13	+	+	+	+	+	–	+	B	+	–	–	–	–	B	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	+	+	+	+	+	–	+	–	+	–	O	–	–	B	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	+	+	+	+	+	–	+	–	+	–	+	–	–	–	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
20	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	O	–
21	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	O	–	–	–	O	–	O	–	–	–	–	–	–	–	–	–	–	–	O	–
22	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	O	–	O	–	–	–	O	–	–	–	–	–	–	–	O	–
23	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	–	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	O	–
24	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	O	–
25	+	+	+	+	+	+	+	–	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–	–	–	O	–
26	+	+	+	+	+	–	+	–	+	–	–	–	–	B	+	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–
27	+	+	+	+	+	–	+	–	+	–	O	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	+	+	+	+	+	–	+	–	+	–	+	–	–	B	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	+	+	+	+	+	–	+	–	+	–	+	–	–	B	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31	+	+	+	+	+	–	+	–	+	–	–	–	–	+	+	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–
32	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
35	+	+	+	+	+	–	+	B	+	–	+	–	–	+	+	–	O	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
36	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
37	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
38	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
39	+	+	+	+	+	–	+	–	+	–	+	–	–	–	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
40	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
41	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
42	+	+	+	+	+	+	+	+	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
43	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
44	+	B	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	O	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
45	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	+	+	+	+	+	+	+	–	+	–	+	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	+	+	+	+	+	–	+	–	+	–	+	–	–	–	+	–	O	–	–	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	+	+	+	+	+	–	+	–	+	–	+	–	–	–	+	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49	+	+	+	+	+	–	+	–	+	–	+	–	–	–	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
50	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
51	+	+	+	+	+	–	+	–	+	–	+	–	–	B	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
52	+	+	+	+	+	–	+	–	+	–	+	–	–	B	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
53	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	O	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–
54	+	+	+	+	+	+	+	–	+	–	+	–	–	B	+	–	O	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	O	–
55	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
56	+	+	+	+	+	–	+	–	+	–	+	–	–	+	+	–	+	–	–	–	–	–	–	–	–	–	O	–	–	–	–	–	–	–	–	–

1 + = acid production.
— = alkali production.
O = neutral.

2 + = gas produced.
— = no gas produced.
B = bubble (not enough to measure).

TABLE 3. — *Summary of Biochemical Data as Regards Fermentation of the 112 Strains of Bacterium Pullorum* — Concluded.

[Acid[1] and gas[2] production.]

Culture	Dextrose		Mannite		Galactose		Levulose		Arabinose		Salicin		Mannose		Xylose		Adonite		Erythrol		Saccharose		Dulcite		Dextrine		Lactose		Raffinose		Inulin		Maltose		Glycerine	
	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas	Acid	Gas
57	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	O	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
58	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
59	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
60	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
61	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	O	−	−	−
62	+	+	+	+	+	+	+	B	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	O	−	−	−
63	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
64	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
65	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
66	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
67	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
68	+	+	+	+	+	−	+	−	+	−	+	−	+		+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
69	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
70	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
71	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
72	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−
73	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
74	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−
75	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
76	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
77	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
78	+	+	+	+	+	−	+	−	+	−	O	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
79	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−
80	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−
81	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
82	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	−	−	O	−	−	−	−	−	−	−
83	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	O	−	−	−	O	−	−	−	−	−	−	−
84	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
85	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−
86	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
87	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
88	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
89	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
90	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
91	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
92	+	+	+	+	+	+	+	B	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
93	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−
94	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
95	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
96	+	+	+	+	+	−	+	−	+	−	+	−	+	−	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
97	+	+	+	+	+	−	+	−	+	−	+	−	+	−	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
98	+	+	+	+	+	−	+	−	+	−	O	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
99	+	+	+	+	+	−	+	−	+	−	O	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
100	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
101	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
102	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
103	+	+	+	+	+	+	+	B	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
104	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
105	+	+	+	+	+	+	+	B	+	−	+	−	+	+	+	−	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
106	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
107	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
108	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	+	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
109	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
110	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
111	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
112	+	+	+	+	+	−	+	−	+	−	+	−	+	+	+	−	O	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

[1] + = acid production.
— = alkali production.
O = neutral.

[2] + = gas produced.
— = no gas produced.
B = bubble (not enough to measure).

A comparison of the tables which have to do with *Bact. pullorum* with those which have to do with *Bact. sanguinarium* shows that *Bact. pullorum* is maltose-dextrine-dulcite negative, while *Bact. sanguinarium* is maltose-dextrine-dulcite positive. All freshly isolated strains of *Bact. pullorum* (139 strains) have produced gas, while the five strains of *Bact. sanguinarium* have never produced gas. The 112 strains of *Bact. pullorum* studied have been maltose-dextrine-dulcite negative. This agrees very well with the work of Hadley. Thus far we have isolated but one organism from chicks, showing typical symptoms of white diarrhœa, which did not produce gas in dextrose. This particular strain was maltose-dextrine-dulcite negative, and therefore would correspond to *Bact. pullorum* B or the anaerogenic pullorum form. During the current year, 1920–21, several anaerogenic forms have been isolated from adult hens, and they were maltose-dextrine-dulcite negative, which in a way helps to substantiate Hadley's claim that the *Bact. pullorum* infecting adult hens is maltose-dextrine-dulcite negative, but anaerogenic. The number of cases thus studied is meager, and future studies with more cases ought to give sufficient data to establish this point. Since Hadley has been able to isolate both aerogenic and anaerogenic forms of *Bact. pullorum* from the eggs of fowls experiencing infections with the maltose-dextrine-dulcite anaerogenic strains, and since the maltose-dextrine-dulcite negative strains isolated by him from chicks have been aerogenic, while all the maltose-dextrine-dulcite negative strains isolated from infections in adult birds have been anaerogenic, the duality of the *Bact. pullorum* type appears to be justified. The work presented in this paper substantiates Hadley's results. Besides, the gas production is of great value as a differential characteristic. Therefore it is essential in making a differential bacterial diagnosis for *Bact. pullorum* to note its special morphological characteristics; to ascertain its fermentation activities in maltose, dextrine and dulcite, and its aerogenicity. Doubtful cultures of *Bact. pullorum* should be submitted to the above biochemical tests before a differential diagnosis is justified. As a routine in this department, all doubtful cultures are tested for aerogenicity in dextrose, and for acidity in maltose; methyl red being used as an indicator for the increased acid production. The data at hand indicate that there are maltose-dextrine-dulcite negative strains which do not produce gas in dextrose, and these, whether found only in adult birds or not, should be classed as the *Bact. pullorum* B, different from the one so generally isolated from chicks, which is maltose-dextrine-dulcite negative, but produces gas in dextrose.

The fowl typhoid (*Bact. sanguinarium*) is characterized, aside from its specific morphology, as an anaerogenic non-motile bacillus. It does not form indol, nor reduce nitrates. It forms H_2S in lead acetate media. It is a maltose-dextrine-dulcite positive organism.

Distribution of Fowl Typhoid in Massachusetts.

During the seasons of 1919–20 and 1920–21, observations were made on all specimens sent to the laboratory for diagnosis, especially to note the presence of *Bact. sanguinarium.* During that time more than 600 different specimens were examined, and this anaerogenic, non-motile bacillus which was maltose-dextrine-dulcite positive was isolated but six times, — three times in the season of 1919–20 and three times in the season of 1920–21. These cases exhibited all the post-mortem findings peculiar to this disease. Especially noticeable were the enlarged spleen and the marked leukemic condition. There were, however, several maltose-dextrine-dulcite negative forms isolated which were anaerogenic, these classifying as *Bact. pullorum* B. During this same period 289 chicks, sent here with a history of bacillary white diarrhœa, were examined, and the true *Bact. pullorum* was isolated from all but one. This one strain was anaerogenic, and persistently gave a faint acid reaction in maltose when methyl red was used as an indicator. From this it would appear that in this one chick we were dealing with an organism which came close to the *Bact. sanguinarium* type. From these findings the writer is led to believe that the fowl typhoid infection in Massachusetts is infrequent, and that the *Bact. pullorum* B type is far from common. In our work of the last few years we have never isolated from eggs a *Bact. pullorum* form which was anaerogenic. All cultures have been aerogenic and have produced little or no acid in maltose, dextrine or dulcite.

Although this represents but two years' observations, there appears to be sufficient evidence to indicate that fowl typhoid is not widely distributed in Massachusetts; that it is not transmitted by the egg; and that *Bact. pullorum* of the B type is found frequently in adult stock.

Does either Bact. Pullorum or Bact. Sanguinarium play Any Part in the so-called "Paralysis" so widely distributed in Massachusetts?

During the course of the studies concerning the diagnosis of *Bact. pullorum*, there were brought to the laboratory many birds suffering with the so-called "paralysis," which even now is assuming a vast economic importance in the poultry industry in Massachusetts. The weakness of the legs and the listlessness of these birds were not essentially different from conditions produced in rabbits when inoculated with pure cultures of *Bact. pullorum.* With this in mind, all specimens exhibiting the paralytic symptoms were examined bacteriologically, with special reference to *Bact. pullorum* and *Bact. sanguinarium.* There were 83 paralytic specimens examined, and from 5 of them only was isolated *Bact. pullorum* of the aerogenic type. None of the 83 specimens exhibited the marked enlarged spleen and leukemic conditions found in fowl typhoid, as known to us in this laboratory. The anaerogenic maltose-dextrine-dulcite positive organism of fowl typhoid was not isolated from any of the 83 specimens. Cultural examinations were made of liver tissue, spleen, intestinal mucosa, ovarian tissues, and lumbar region of the spinal cord. In this so-called "paralysis" all birds during life showed a rather bright red comb, the paleness being evident only a short time before death. There was never found at autopsy a marked leukemia. In fowl typhoid this leukemic condition is highly prominent, and for this reason Moore has called this paratyphoid type of infection "infectious leukemia." Hadley has observed a similar epidemic in fowls showing pronounced leukemic symptoms associated with *Bact. pullorum.* The writer has never observed this condition in relation to *Bact. pullorum* infections in adult birds.

From these observations on the 83 paralytic birds, with only 5 showing the presence of the *Bact. pullorum* infection, — these five probably having carried the infection since chickhood, — the evidence does not indicate that the paralytic disease so widely distributed at certain periods of the year in Massachusetts is due to the presence of either the pullorum or sanguinarium type.

Influence of Infection upon the Hatching Quality of Eggs and upon the Viability of Young Stock.

In 1917 and 1918 several sets of experiments were carried out under the best known conditions for poultry husbandry. Eggs from 60 hens known to have reacted positively to the agglutination test were set in an electrobator. When tested at the end of the first seven days of incubation, 30 were found to be infertile and 2 were found dead in the shell. Of the 28 left, 10 were hatched; 3 chicks died at the end of the first day and *Bact. pullorum* (aerogenic type) was isolated from the unabsorbed yolk. All eggs containing fully developed chicks were examined especially for *Bact. pullorum,* with the following results. The egg number in each case represents the number of the hen laying the egg.

TABLE 4. — *Results of Tests for Bacterium Pullorum in Dead Chicks from Eggs laid by Positively Reacting Birds.*

Egg Number.	Bact. pullorum.	Egg Number.	Bact. pullorum.
8001	+	7925	—
8384	+	7998	—
8388	—	8430	+
8002	—	8430	—
8002	—	8565	+
8430	+	8388	+
7925	—	7998	+
8565	—	8430	—
8001	+	8384	—

+ = present. — = not present.

From this table it will be seen that with the methods used it was not possible to detect *Bact. pullorum* in all the dead chicks, although adult hens were all positively reacting to the agglutination test. From 8, *Bact. pullorum* was isolated without difficulty; from the other 10, the cultures were negative.

After three months, following out three sets of incubation, the author was able to obtain from the three sets of eggs set, 60 in each lot, all from positively reacting hens, 7 livable chicks on the first set, 9 on the second set, and 9 on the third set, and these chicks were all given the numbers of the parent stock from which they came: 7811, 7895, 7925, 7997, 7998, 8001, 8002, 8020, 8082, 8084, 8094, 8139, 8171, 8180, 8202, 8204, 8294, 8384, 8388, 8389, 8430, 8431, 8544, 8565, 8810. These 25 birds, all reared from positively agglutinating hens, were yarded together and blood taken at various times to determine whether their blood would show any signs of agglutinative powers.

When the chicks had grown to a weight of at least 400 grams, they were put together in the yard on Aug. 10, 1917. The following table shows the weight of each bird at that time: —

TABLE 5. — *Weight of Chicks on Aug. 10, 1917.*

Chick Number.	Weight (Grams).	Chick Number.	Weight (Grams.)
7811	870	8180	680
7895	1,200	8204	450
7925	1,240	8202	580
7997	860	8294	780
7998	1,249	8384	620
8001	1,160	8388	530
8002	1,130	8389	540
8020	680	8430	540
8082	950	8431	380
8084	1,490	8544	510
8094	730	8565	530
8139	1,050	8810	670
8171	780		

Agglutination tests were run on these birds, the first being on July 17, 1917. The following table shows the reactions for this and subsequent tests: —

TABLE 6. — *Records of Agglutination Tests on Chicks hatched from Eggs laid by Positively Reacting Hens.* [1]

Chick Number.	July 17 and 18, 1917. Dilution of serum.					July 21, 1917. Dilution of serum.					Aug. 3, 1917. Dilution of serum.					Aug. 26, 1917. Dilution of serum.					Nov. 7, 1917. Dilution of serum.				
	1–100.	1–200.	1–500.	1–1000.	1–2000.	1–100.	1–200.	1–500.	1–1000.	1–2000.	1–100.	1–200.	1–500.	1–1000.	1–2000.	1–100.	1–200.	1–500.	1–1000.	1–2000.	1–100.	1–200.	1–500.	1–1000.	1–2000.
7811	?	?	?	?	?	C	?	?	?	?	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
7895	?	?	?	?	?	0	0	0	0	0	C	C	C	0	0	?	?	?	?	?					
7925	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
7997	C	C	0	0	0	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
7998	0	0	0	0	0	0	0	0	0	0	C	C	0	0	0	?	?	?	?	?	?	?	?	?	?
8001	0	0	0	0	0	?	?	?	?	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8002	0	0	0	0	0	C	0	0	0	0	C	C	0	0	0	?	?	?	?	?	0	0	0	0	0
8020	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
8082	C	?	?	?	?	0	0	0	0	0	C	C	0	0	0	C	C	0	0	0					
8084	?	?	?	?	?	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	0	0	0
8094	0	0	0	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
8139	?	?	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8171	?	?	?	?	?	?	?	?	?	?	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
8180	C	C	C	C	C	C	C	C	C	C	C	0	0	0	0	C	C	C	0	0	C	C	C	C	C
8202	0	0	0	0	0	0	0	0	0	0						C	C	C	C	C	C	C	C	C	C
8204	?	?	?	0	0	C	C	C	C	?	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
8294						0	0	0	0	0	C	C	C	C	C	C	C	0	0	0	C	C	C	C	C
8384	C	C	C	C	C	0	0	0	0	0	C	0	0	0	0	C	C	C	0	0	C	C	C	C	C
8388	?	?	?	?	?	C	C	C	C	C	?	?	?	?	?	C	C	0	0	0	C	C	0	0	0
8430	?	?	?	0	0	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
8565	?	?	?	?	?	C	C	C	C	C	C	C	C	C	0	C	C	C	C	C	C	C	C	C	C
8810	?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	?	?	?	?	?					

[1] The symbols indicating various degrees of agglutination have been taken from Hadley, Journal of Immunology, Vol. 2, p. 463, 1917, as follows: C=complete agglutination; ?=doubtful agglutination; 0=no agglutination.

These experiments indicate that in chicks hatched from eggs laid by positively reacting hens, at least six months' time should elapse before the normal agglutination power of such sera would be sufficiently definite to furnish indication of past or present infection. The birds reared from hens 8001, 8139 and 8810 never showed any agglutinative power to their blood sera. The length of time a serum maintains its agglutination power has not as yet been determined.

The Present Status of the Specificity of the Agglutination Test as a Means of Control of Bacterium Pullorum Infection in Young Chicks.

During the last few years the agglutination test has become a popular means of recognition in the domestic fowl of those individuals which have contracted *Bact. pullorum* infections in chickhood; and consequently, as adult productive fowls, may have become, through infections in their ovaries, carriers of infection to the offspring. Several writers have demonstrated that there are certain factors which have influenced the test and which suggest the need of modification of the method in the direction of securing a higher degree of specificity. Hadley suggests that we stand in need of a means of diagnosis which shall distinguish between a latent (presumably ovarian) and a past infection. The data presented up to date indicate that not all adult hens with *Bact. pullorum* have infections localized in the ovaries; and also that not all infection has its origin in an attack of bacillary white diarrhœa experienced in the chick stage. This point, as Hadley suggests, is of less significance in its bearing upon the validity of the results of agglutination tests for *Bact. pullorum* infection than is the question of the specificity of the test. This author as well as others has demonstrated the interagglutinability of *Bact. pullorum*, fowl typhoid and other antigens in both *Bact. pullorum* and fowl typhoid serum. Fowls which have been experimentally immunized against different types of fowl typhoid possess serum which agglutinates *Bact. pullorum* antigens quite as well as it agglutinates its homologous antigen. According to these data the agglutination test for the recognition of *Bact. pullorum* infection appears to lose some of its claim to specificity; and to this extent, without carefully going over the results as obtained in field and laboratory co-operating, it may be open to criticism.

If all operations both in field and laboratory are considered, however, the reader will be convinced that the test yields valuable results. From our work, already reported, during the seasons of 1919–20 and 1920–21, there were only six cases where the anaerogenic type of organism was isolated and the post-mortem examinations revealed the enlarged spleen associated with leukemic conditions. This indicates that, at least so far as this laboratory has been called upon to make examinations, fowl typhoid infections are infrequent. That all infections are localized in the ovary is yet to be proven. It can be said, however, that the ovarian infections are not rare, and when they are present they persist. During the course of the examination of hundreds of eggs for *Bact. pullorum* infection, only the true aerogenic form of *Bact. pullorum* was isolated. Strains of these cultures, even after four years, maintained this aerogenic property and were maltose-dextrine-dulcite negative. Therefore these studies indicate that fowl typhoid is not transmitted to the egg. In all of our work in the bacteriological examination of young chicks, in all cases showing large unabsorbed yolks, we have been able to isolate only the aerogenic type of organism, and this in hundreds of cases. This shows an apparent lack of susceptibility of young stock to the *Bact. sanguinarium* type of infection, and appears to substantiate the work of Dr. Hadley, who states that he has examined large numbers of cultures derived from young stock, but has not encountered among them the *Bact. sanguinarium* type.

In this laboratory hundreds of agglutination tests have been made to demonstrate the interagglutinability of *Bact. pullorum* with *Bact. sanguinarium*, *B. typhosus*, *B. paratyphosus* A, and *B. paratyphosus* B. The results obtained here agree with those from other laboratories: *i.e.*, that the agglutinative tests are sufficiently definite for grouping the fowl typhoid and pullorum types together, both demonstrating the same intimate relation to typhoid bacilli. In every test made, the *Bact. pullorum* immune serum agglutinates typhoid antigen better than typhoid serum agglutinates pullorum antigen. *Bact. sanguinarium* immune serum agglutinates *Bact. pullorum* much better than it does typhoid. There has never been demonstrated any indication of an affinity of interagglutinability between *B. avisepticus* (fowl cholera) and the pullorum and sanguinarium types. While it is true that by our present methods it is difficult to differentiate sanguinarium and pullorum by agglutination, this does not mean that application of the test will not yield valuable results. Already, from the work of three years, the typical maltose-dextrine-dulcite positive anaerogenic fowl typhoid organism has been isolated six times, and in this study more than 600 specimens were examined. This indicates that fowl typhoid is not widespread, at least in Massachusetts.

From the preceding biochemical data the establishment of *Bact. pullorum* and *Bact. sanguinarium* as separate types is justifiable. Therefore if it can be proven that breeding birds showing a positive agglutination reaction may lay eggs, from which are hatched chicks developing white diarrhœa symptoms, and at death the internal organs yield cultures which demonstrate morphologically an organism which is slender, non-motile, gram-negative, gelatine non-liquefying, and is aerogenic, demonstrating no acidity in maltose, dextrine and dulcite, the agglutination test would not be invalid as an economic measure in the identification of this infection. With this in mind, an experiment was carried out to this end.

Twenty breeding flocks were selected, all showing positively reacting birds, and the following spring all the dead chicks from these places were examined bacteriologically, with special reference to identifying the small gram-negative, maltose-dextrine-dulcite negative organism which was aerogenic. The following table shows the details of the tests: —

TABLE 7. — *Results on Identification of Cultures isolated from Dead Chicks which had been hatched from Eggs laid by Positively Reacting Breeding Birds.*

[Materials for study obtained from 20 different parts of Massachusetts.]

Flock Number.	Breeding Birds.		Cultures isolated from Dead Chicks.	(Fermentation) Acid in —			Gas Production (Aerogenicity) in Dextrose.	Agglutinability by Pullorum Serum.	Identification.
	Number in Flock.	Number with Positive Agglutination Test.		Maltose.	Dextrine.	Dulcite.			
1	51	16	2 Y	—	—	—	+	+C (1-400)	*Bact. pullorum* A
			3 H	—	—	—	+	+C (1-400)	
			3 Y	—	—	—	+	+C (1-400)	
2	219	26	1 L	—	—	—	+	+C (1-400)	*Bact. pullorum* A
			2 Y	—	—	—	+	+C (1-400)	
			3 Y	—	—	—	+	+C (1-400)	
			4 H	—	—	—	+	+C (1-400)	
3	216	45	29 Y	—	—	—	+	+C (1-400)	*Bact. pullorum* A
4	51	20	22 L	—	—	—	+	+C (1-400)	*Bact. pullorum* A
5	36	3	24 Y	—	—	—	+	+C (1-400)	*Bact. pullorum* A
			25 Y	—	—	—	+	+C (1-400)	
6	1,194	244	29 Y	—	—	—	+	+C (1-400)	*Bact. pullorum* A
7	784	14	31 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			32 Y	—	—	—	+	+C (1-200)	
			33 Y	—	—	—	+	+C (1-200)	
8	250	51	39 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			40 L	—	—	—	+	+C (1-200)	
9	89	13	45 H	—	—	—	+	+C (1-200)	*Bact. pullorum* A
10	393	29	52 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			53 L	—	—	—	+	+C (1-200)	
			54 L	—	—	—	+	+C (1-200)	
11	138	21	60 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
12	76	6	61 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
13	882	129	1 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			2 Y	—	—	—	+	+C (1-200)	
			3 Y	—	—	—	+	+C (1-200)	
			4 H	—	—	—	+	+C (1-200)	
14	116	33	2 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			3 H	—	—	—	+	+C (1-200)	
			3 Y	—	—	—	+	+C (1-200)	
15	264	71	1 Y	—	—	—	—	+C(1-200)	*Bact. pullorum* ?
16	110	46	2 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
17	239	33	1 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
18	66	10	1 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
19	38	11	2 Y	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			3 H	—	—	—	+	+C (1-200)	
			3 Y	—	—	—	+	+C (1-200)	
20	407	103	1 L	—	—	—	+	+C (1-200)	*Bact. pullorum* A
			2 Y	—	—	—	+	+C (1-200)	
			3 Y	—	—	—	+	+C (1-200)	
			4 H	—	—	—	+	+C (1-200)	

Y=unabsorbed yolk; H=heart blood; L=liver.

The results presented in this table need no comment. It can readily be seen that, with the exception of one culture obtained from flock No. 15, all cultures obtained from dead chicks which had been hatched from positive-reacting birds were maltose-dextrine-dulcite negative, and produced gas in dextrose. This is significant in that these flocks were widely distributed, and the only exception to this rule was the one noted above. This culture was maltose-dextrine-dulcite negative and was anaerogenic. At any rate, it gave none of the reactions for *Bact. sanguinarium.* On this experiment were 5,619 breeding hens and 924 were positive reactors, giving a positive agglutination up to dilutions of 1,000 and over. It is reasonable to believe that these results would be substantiated by a repetition of the experiment. While there are, as already noted, certain factors which have influenced the test and which may suggest need of modifications, — such as the validity of the agglutination tests, based on interagglutinability of *Bact. pullorum*, *Bact. sanguinarium* and other antigens in both *Bact. pullorum* and *Bact. sanguinarium* serum, — yet the fact remains that in the twenty flocks mentioned the agglutination test definitely located infection in 924 birds in a total number of 5,619. The differential characteristics of the cultures isolated from dead chicks which had been hatched from the eggs laid by these positive-reacting birds proved to be typical *Bact. pullorum*, conforming morphologically and biochemically to the standard set as a result of fermentative, serological and morphological studies completed.

After all is said about chances of error with the test, data are constantly being accumulated which indicate that the agglutination when carefully controlled through epidemiological work is at present the best method we have of locating *Bact. pullorum* infection and furnishing poultrymen a starting point for its elimination.

Summary.

From the foregoing data the following conclusions appear justified concerning the diagnosis of *Bact. pullorum* infection in the domestic fowl: —

1. From the fermentation studies conducted over a period of three years, it was found that *Bact. pullorum* is maltose-dextrine-dulcite negative and aerogenic, while all cultures of *Bact. sanguinarium* studied have been maltose-dextrine-dulcite positive and anaerogenic. These characteristics are constant. Whenever there has been question as to cultural and morphological differentiations, these investigations have shown that the biochemical tests have aided in making a final decision. Variations in morphology of the pullorum strains are frequent; therefore doubtful cultures should be submitted to the maltose-dextrine-dulcite test and checked by gas production in dextrose. Experience has shown that this procedure should be followed as a routine in all laboratories having to do with the pullorum problem.

2. From the examination of 600 avian specimens for the anaerogenic, non-motile, maltose-dextrine-dulcite positive form which produced en-

larged spleens associated with marked leukemic conditions, it was of some significance that the true sanguinarium culture was identified only six times. Chick examinations conducted during this same period, representing several hundred examinations, all yielded typical pullorum cultures. There was but one exception, and this culture was probably an atypical pullorum form which had become anaerogenic. In the examination of the adult avian specimens, the maltose-dextrine-dulcite negative forms isolated from several dead hens indicate that Hadley is correct in his contention that *Bact. pullorum* may assume a dual rôle: *Bact. pullorum* A being maltose-dextrine-dulcite negative and aerogenic, infecting young chicks; and *Bact. pullorum* B being maltose-dextrine-dulcite negative and anaerogenic, infecting adult hens. Cultures from eggs have always been aerogenic. If knowledge of *Bact. sanguinarium* is based upon the anaerogenicity of cultures, the absence of this property in cultures isolated from adult hens, chicks and eggs sent from all parts of the State would appear to indicate that fowl typhoid is not widely distributed in Massachusetts.

3. From pathological and bacteriological examination of 83 birds suffering with the so-called "paralysis," the evidence at hand does not indicate that the disease, so widely distributed at certain periods of the year, is due to the presence of the pullorum or sanguinarium type of organism.

4. The agglutination test has become a popular means of recognition in the domestic fowl of those individuals which have contracted infections in chickhood, and consequently, as adult productive fowls, may have become, through infections in their ovaries, carriers of infection to the offspring. During this investigation hundreds of agglutination tests have been made, demonstrating that there is an interagglutinability of *Bact. pullorum* with *Bact. sanguinarium*, *B. typhosus*, *B. paratyphosus* A and *B. paratyphosus* B antigens, with a consequent tendency to make the test lose in terms of specificity. The fact remains, however, as a result of experiments in this department, that in twenty flocks studied, representing 5,619 breeding birds, the test located infection in 924. Furthermore, the differential characteristics of the cultures isolated from dead chicks which had been hatched from eggs laid by these positively reacting birds proved them to be typical *Bact. pullorum*, conforming morphologically and biochemically to the standard set for this organism. Therefore, from these data, the conclusion seems justified that the agglutination test, when carefully controlled through epidemiological work, is at present the best method we have for locating *Bact. pullorum* infection and furnishing to poultrymen a starting point for its elimination.

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BULLETIN No. 210.

DEPARTMENT OF ENTOMOLOGY.

INJURY TO FOLIAGE BY ARSENICAL SPRAYS.

II. CALCIUM ARSENATES AND ARSENITES.
III. NOTES ON OTHER ARSENICALS.

BY H. T. FERNALD AND A. I. BOURNE.

In Bulletin No. 207 of this station the effects of lead arsenate sprays on foliage were discussed. In a similar way this bulletin gives the results of studies with calcium arsenates and arsenites, and the factors which appear to cause foliage injury following their use, together with notes on other arsenicals.

As in the case of the lead arsenates, the chemical work was done under the supervision of Dr. E. B. Holland of the Department of Plant and Animal Chemistry of the Experiment Station, and the applications of the materials and studies of the results were made by the Department of Entomology. All the statements made in Bulletin No. 207 with reference to responsibility for the various parts of the work, methods of application, and adequacy of methods, apply also to this part of the investigation.

II. CALCIUM ARSENATES AND ARSENITES.

Materials.

Pure Acid Calcium Arsenate. — To obtain pure calcium arsenate from manufacturers proved impossible, and a quantity of this substance was finally prepared by the Department of Plant and Animal Chemistry of this station. It was the acid arsenate ($CaHAsO_4.H_2O$) and was a white powder consisting of rhombic crystals varying in size and with about 1 per cent of them broken. Analyzed, it gave the following: —

	Air Dry.	Dried.
Water	.120	–
Calcium oxide, CaO	28.300	28.334
Arsenic pentoxide, As_2O_5	57.955	58.025
Water of combination	13.630	13.646
	100.005	100.005

The powder, therefore, was a practically pure acid calcium arsenate.

This substance proved very soluble on standing twenty-four hours, 44.82 per cent of the arsenic pentoxide entering into solution. The addition of milk of lime to the material was therefore tried, and after 1 per cent of this had been added, the amount dissolved was only .17 per cent. As finally used, the spray was accordingly prepared as follows: —

Four pounds of quicklime were slaked in about 40 gallons of water, just enough water being added at a time to maintain a brisk action without "drowning" the lime. After the slaking was completed, enough more water to make 50 gallons in all was added. Eighty-five hundredths of a pound of the arsenate was then mixed in, this being the amount calculated as necessary to give the spray the same strength of arsenic pentoxide as that of the lead arsenate sprays, in order to make the tests comparative. The material was strained into the spray pump and kept well agitated.

Commercial Calcium Arsenate. — This was a bulky, white powder consisting of minute spherical particles. It was purchased in the market, and on analysis proved not to be similar to the pure material considered above, but a combination of calcium and arsenic acid, with a considerable excess of lime. It might, perhaps, be fairly described as a basic lime arsenate. Its analysis gave —

	Per Cent.
Water, H_2O	1.38
Water in combination and occluded	2.92
Ferric and aluminum oxides	1.30
Calcium oxide, CaO	45.47
Magnesium oxide, MgO	.68
Sodium oxide, Na_2O	1.09
Arsenic pentoxide, As_2O_5	46.61
Sulfur trioxide, SO_3	.18
Chlorine, Cl	.02
Soluble silica, SiO_2	.16
Acid insoluble matter	.13
	99.94

This was not a pure material, but the impurities were not of such a nature nor present in such amounts as to be likely to cause injury to foliage.

Tests of the solubility of this material gave only a trace of arsenic pentoxide as dissolving after twenty-four hours' treatment with water. In order to make a direct comparison of this substance with the pure acid salt, milk of lime was added as described above, and 1.14 pounds of the arsenate were used for each 50 gallons of spray, this amount providing enough arsenic pentoxide to equal that used in the other tests.

Calcium Metarsenite. — Two samples of this material (both pastes) were tested, having been received from manufacturing companies. Their analyses follow: —

I.

	Per Cent.
Water, H_2O	67.87
Calcium oxide, CaO	6.78
Arsenic trioxide, As_2O_3	23.87
Arsenic pentoxide, As_2O_5	.09
Magnesium oxide, MgO	.05
Sodium oxide, Na_2O (estimated)	.70
Chlorine, Cl	.80
Insoluble matter	.01
	100.17

The original composition of this material was probably about as follows: —

	Per Cent.
Water, H_2O	67.87
Calcium ortho arsenate, $Ca_3(AsO_4)_2$	.18
Calcium metarsenite, $Ca(AsO_2)_2$	30.31
Magnesium metarsenite, $Mg(AsO_2)_2$	.30
Sodium chloride, $NaCl$	1.32
Insoluble matter	.01
	99.99

This substance gave 11.58 per cent of soluble arsenic trioxide on standing in water for twenty-four hours, showing at once its dangerous nature when applied to foliage. When mixed with milk of lime, however, the amount soluble was greatly reduced, but even then safety could not be obtained with any certainty.

II.

	Per Cent.
Water, H_2O	79.03
Arsenic trioxide, As_2O_3	16.20
Arsenic pentoxide, As_2O_5	.03
Calcium oxide, CaO	4.51
Magnesium oxide, MgO	.05
Sodium oxide, Na_2O (estimated)	.07
Chlorine, Cl	.03
Organic matter, etc.	.08
Insoluble matter	.01
	100.01

The original composition of this material was probably substantially as follows: —

	Per Cent.
Water, H_2O	79.03
Calcium ortho arsenate, $Ca_3(AsO_4)_2$	.06
Calcium metarsenite, $Ca(AsO_2)_2$	20.34
Magnesium metarsenite, $Mg\ (AsO_2)_2$	.30
Sodium arsenite, $NaAsO_2$	.13
Sodium chloride, $NaCl$	.05
Organic matter, etc.	.08
Insoluble matter	.01
	100.00

The arsenic in this material, also, proved so soluble on standing in water as to make it unsafe for application to foliage. It was tested both in water alone and with the addition of various percentages of milk of lime. With both samples, enough was taken to give the standard amount of arsenic, so that the treatments should be comparable with those made with the lead arsenates and lime arsenates.

Experimental Work.

The materials described above were sprayed upon the apple, cherry, peach, pear, plum and elm, under the same conditions as given in Bulletin No. 207, and the results obtained follow.

Pure Acid Calcium Arsenate with 1 Per Cent Milk of Lime. — The apple, sprayed with this material in clear weather, shows injury above the safety line (Fig. 1, AB), from high temperature with low humidity to low temperature with high humidity. The line for the greater part of its course runs lower than the safety line for lead arsenates, though at the high humidity end the reverse is true to a slight degree. As the general safety line for the apple is much below most of those given in clear weather, the difference is more marked by comparing any of the clear weather lead arsenate safety lines in Bulletin No. 207 with Fig. 1, than when the general one is used. The evidence is that pure acid calcium arsenate with 1 per cent milk of lime cannot be used on the apple at as high temperatures and humidities as the lead arsenates in clear weather. This is true, also, for cloudy weather, though the difference is not so great.

On the pear, clear-weather tests gave six cases of injury above the safety line (Fig. 2, AB), which runs considerably higher than in the case of the apple. In the cloudy weather tests (Fig. 2, CD), as was the case with the lead arsenates, the pear is evidently much more resistant to spray injury than the apple.

In the case of the cherry (Fig. 3), the leaves are more liable to injury than the apple, but less so than the plum. The cloudy weather safety lines for the cherry and plum (Figs. 3 and 4, CD) are very nearly the same, however. With the plum, temperature seems to play an important part, injury beginning in clear weather at quite a low point, while high humidity seems to be less dangerous (Fig. 4, AB).

SAFETY LINES FOR SPRAYING WITH PURE ACID CALCIUM ARSENATE.

AB, clear weather; CD, cloudy weather.

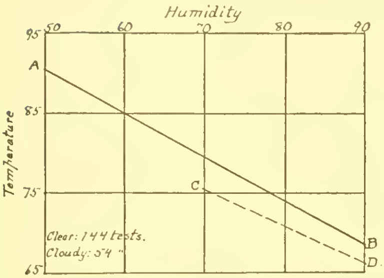

FIG. 1. — Apple.

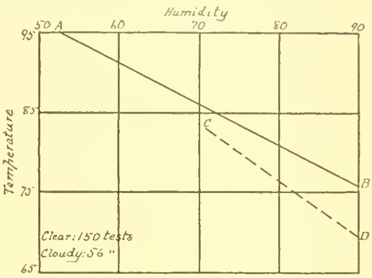

FIG. 2. — Pear.

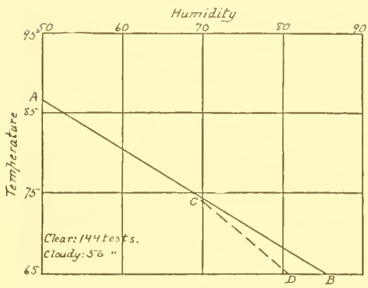

FIG. 3. — Cherry.

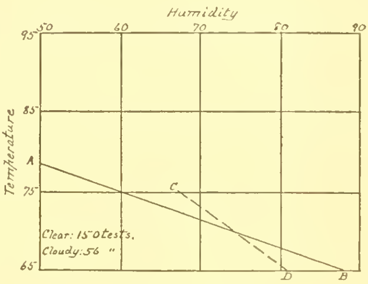

FIG. 4. — Plum.

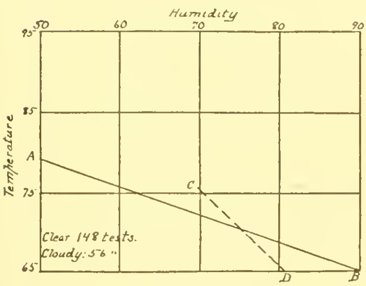

FIG. 5. — Peach.

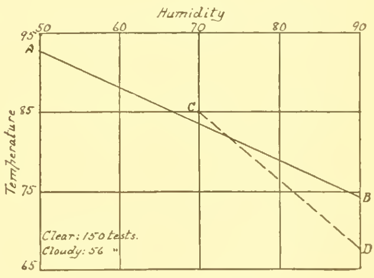

FIG. 6. — Elm.

The peach (Fig. 5) quite closely follows the plum in its resistance to calcium arsenate, and the two figures (4 and 5) show no more difference than might perhaps easily disappear could a greater number of tests have been made.

The elm (Fig. 6) is evidently less resistant to pure acid calcium arsenate than the pear, as eleven cases of injury were obtained above the safety line AB of the figure, in clear-weather tests, and the line itself runs considerably lower than that for the pear. In cloudy weather the elm also appears to be more easily injured at high humidities, even if the temperature is low.

Commercial Calcium Arsenate with 1 Per Cent Milk of Lime. — On the apple (Fig. 7) this material gives results differing little from those obtained with the pure acid calcium arsenate described above. The cloudy weather tests suggest a little greater safety with the commercial material at medium combinations of temperature and humidity, but the rather small number of tests obtained makes this difference less significant than if similar results had been shown by a larger number.

In the case of the pear (Fig. 8) no injury was obtained following any of the tests, and AB is simply placed along the highest tests obtained. Whether higher combinations of temperature and humidity would have shown injury could they have been obtained, is, of course, unknown. The cloudy weather safety line CD is more satisfactorily located, three cases of injury having shown that the line could not be placed higher.

Tests of the cherry (Fig. 9) give in general an agreement between the two materials (compare Figs. 3 and 9), though the commercial substances seem, as in the case of the apple, to be a little safer at medium combinations of temperature and humidity.

With the plum (Fig. 10) it would seem that the commercial material can be used with safety at a considerably higher temperature than the pure when the humidity is low (86° as compared with 79° at 50° humidity). Aside from this, nothing of significance appears on comparing Figs. 4 and 10.

On the peach (Fig. 11) the two materials give almost identical results (compare Figs. 5 and 11). On the elm (Fig. 12) the commercial article appears to be safer in clear weather than the pure substance (compare Figs. 6 and 12), although one doubtful injury at 85° humidity suggests that the point B on Fig. 12 may be too high.

Comparison of the safety lines obtained on the different kinds of foliage tested with commercial calcium arsenate in clear weather brings out several points of interest. The elm (Fig. 13, 2) would at first seem to be more resistant than the pear (1), particularly at high T and low H. It should be remembered, however, that line 1 was located along the highest tests obtained, no injury showing up to that line, and no tests being available above it. It is not improbable that this line could go considerably higher than where it is now located. The cherry (4) is more resistant than the plum (5) at high T, but slightly the reverse holds at high H, and both, Safety Lines for Spraying with Commercial Calcium Arsenate.

AB, clear weather; CD, cloudy weather.

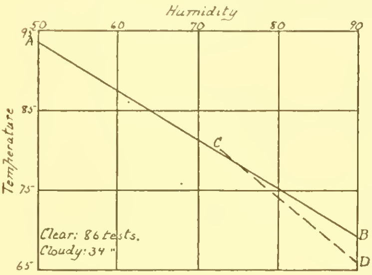

Fig. 7. — Apple.

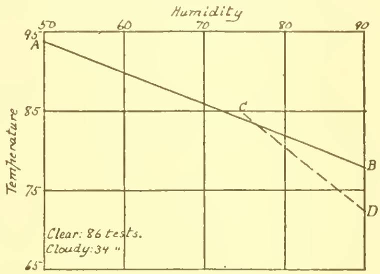

Fig. 8. — Pear.

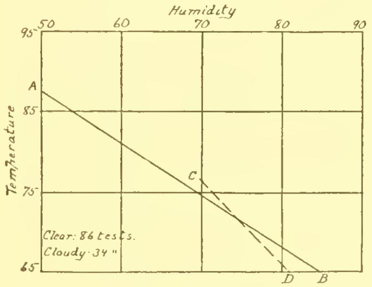

Fig. 9. — Cherry.

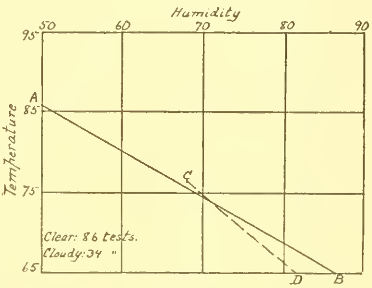

Fig. 10. — Plum.

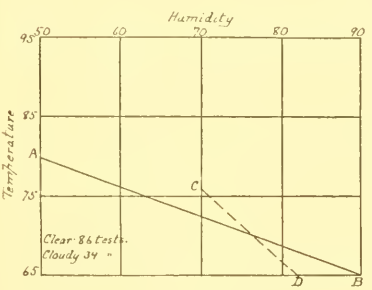

Fig. 11. — Peach.

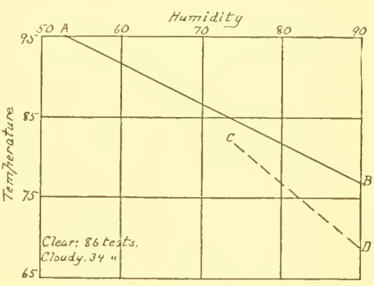

Fig. 12. — Elm.

at this end of the figure, are less resistant than the peach (6), though at high T the latter is considerably less resistant than the other two.

In cloudy weather (Fig. 14) the pear, elm and apple show about the relative relations to each other that would be expected from the studies on lead arsenates, while the cherry, plum and peach are almost identical for the high H limit of safety, and nearly so at the other ends of their safety lines. Such differences as they do show might easily disappear were more tests available, though, on the other hand, such tests might have led to greater differences.

Finally, it is evident that there is a wide difference in the safety lines, and that the spraying of different kinds of trees cannot always be done with safety on the same day. It may be perfectly safe to spray apples on a day when spraying plums, peaches or even cherries might prove disastrous.

Calcium Metarsenite. — The two samples of this substance described above, produced injury on the foliage of all the kinds of trees tested, within two or three days after the application, the injury increasing until the leaves were practically destroyed and dropped off. Though the addition of milk of lime appeared to bring down the solubility of the arsenic within reasonable safety limits in laboratory tests, this did not appear to hold under field conditions, even when the milk of lime was increased to 3 per cent, so further investigation of this material was given up.

III. NOTES ON OTHER ARSENICALS.

Magnesium Arsenate. — This substance, sent in by an insecticide manufacturing company for trial, was tested on the same basis as the other materials. Two hundred and eight clear-weather tests were made at temperatures and humidities ranging from T92 H54 through T86 H70 and T80 H80 to T77 H81, for the high limits, and as low as T78 H55 and T67.5 H 69. In every case, no matter how low T and H were, injury developed on all the trees except the pear and one or two tests on the elm. Apparently, spraying with magnesium arsenate is unsafe at almost any combinations of T and H, except on the pear, where the higher combinations become unsafe, and possibly on the elm, where at low combinations only traces of injury were evident.

In cloudy weather 108 tests were made at combinations of T and H as low as T73 H76 and T67 H72, and as high as T82 H74, T78 H84 and T68 H90. In every test injury, often very serious, followed, except in two instances on the pear.

As a general conclusion from these tests, therefore, magnesium arsenate is not a safe material for spraying under any conditions.

Zinc Arsenite. — Two samples of this material, received from different manufacturers, were tested in 1913. Both were finely divided, bulky powders, light and "fluffy." They were applied, at the rates of 1 pound and $1\frac{1}{2}$ pounds in 50 gallons of water, to the same kinds of trees as were

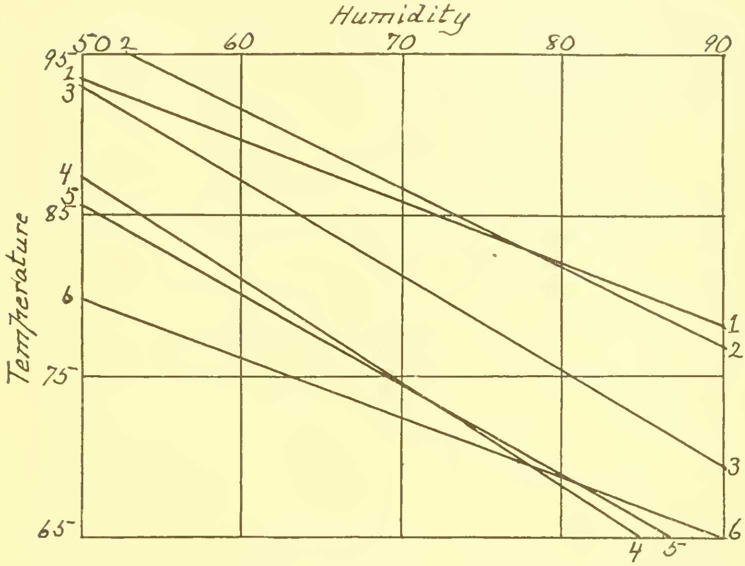

FIG. 13. — Safety lines for spraying with commercial calcium arsenate in clear weather: 1, pear; 2, elm; 3, apple; 4, cherry; 5, plum; 6, peach.

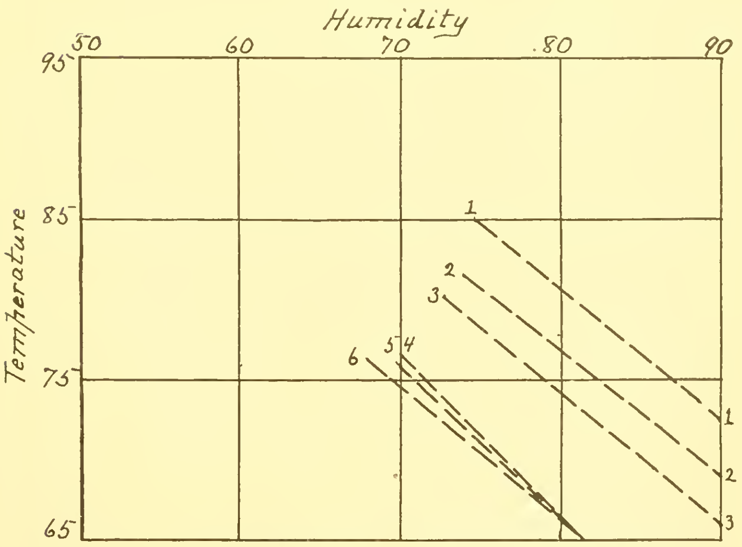

FIG. 14. — Safety lines for spraying with commercial calcium arsenate in cloudy weather: 1, pear; 2, elm; 3, apple; 4, cherry; 5, peach; 6, plum.

used for the other tests, and in every case injury followed, generally severe. Clear or cloudy weather seemed to give little difference in the results, and spraying at low T and H combinations produced injury as certainly as with high combinations of these factors. Extensive tests of zinc arsenite, therefore, were not continued.

SUMMARY.

1. Pure acid calcium arsenate is not on the market. Tests with it indicate in a general way that the same factors determining injury to foliage hold good as with the lead arsenates, but that the safety lines run lower.

2. With commercial calcium arsenate the safety lines run about as high (in some cases a little higher) as with the pure material, but lower than with the lead arsenates. In the case of the peach, however, the safety line does not differ greatly from that obtained with the lead arsenate powder.

3. It is possible that the excess of lime in the commercial calcium arsenate may be sufficient to prevent the arsenic pentoxide from entering into solution. Further tests are needed on this point, as considerable time and bother can be saved if the addition of milk of lime is unnecessary.

4. In general, lime arsenate does not give as satisfactory results as the lead arsenates, the range of T and H combinations at which it is safe being more limited.

5. The spraying of different kinds of trees with commercial calcium arsenate cannot always be done with safety on the same day. The treatment may be safe on some kinds of trees under conditions which make it dangerous to others.

6. Calcium metarsenite is not safe for use on fruit tree foliage.

7. The same is true for magnesium arsenate and zinc arsenite — at least for the samples tested.

BULLETIN No. 211.

DEPARTMENT OF POULTRY HUSBANDRY.

CHANGES IN EGG PRODUCTION IN THE STATION FLOCK.

BY H. D. GOODALE AND RUBY SANBORN.

Introduction.

For the past eight years the work of the Massachusetts Agricultural Experiment Station with poultry has centered about the problem of breeding better layers. A certain measure of success has been reached. The present paper is a descriptive history of the work. The theory that is under test, the plan of procedure, the results secured to date, with such comment as seems to be required to prevent misinterpretation of the data, with such suggestions as can be offered to the breeder, are presented.

The Working Hypothesis.

The studies were begun in December, 1912. It was then supposed that the inheritance of fecundity was a simple two-factor Mendelian matter, but it was not long before it gradually became clear that, with Rhode Island Reds, the egg record made by a bird was the result of the combined action of a number of inheritable characteristics.

Simplifying matters as much as possible, five main characteristics may be recognized, namely: —

1. Maturity.
2. Rate (intensity).
3. Broodiness.
4. Point at which production ceases (persistency).
5. Winter pause.

Each component is very variable. Resulting egg records from combinations of these five variable characteristics are illustrated in Figs. 1 and 2. In Fig. 1 are used the two extremes only of each of the five components, which make 32 possible combinations, each illustrated by an actual

FIG. 1. — Typical Egg Records.
Illustrative of the part played by several factors in determining the number of eggs laid.

BAND NUMBER	FORMULA	DATE HATCHED	AGE AT FIRST EGG	NUMBER EGGS PER MONTH SEP	OCT.	NOV	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV	365 DAYS	TOTAL
B 357	ENFCA	MAR 25	187	3	25	25	19	22	18	24	21	27	28	22	28	26	17		286	305
B 8324	ENFCQ	APR 4	192		10	19	23	19	18	24	21	23	23	25	23	10			238	238
B 8566	ENFPA	APR. 11	185		12	23	18	20	1	25	25	27	22	26	23	23	12		254	257
B 8355	ENFPQ	APR 4	177	3	20	22	26	4	16	18	21	26	25	22	25	6			232	232
B 8336	ENSCA	APR. 4	185		11	21	18	16	14	18	16	16	16	19	20	18	8		206	211
B 3033	ENSCQ	MAR. 31	193		15	10	14	15	16	19	17	20	12	9					147	147
B 24	ENSPA	MAR. 18	191	4	22	9	1	13	13	18	20	17	15	18	17	17	10		181	194
B 4440	ENSPQ	MAY 5	187			10	16	12	10	13	13	17	9		15	4			119	119
8490	EBFCA	APR 30	170		13	26	29	25	20	21^{B}	17	$^{B}12$	$^{B}14$	$^{B}14$	$^{B}1$	12	8		210	212
B 3245	EBFCQ	APR. 7	182		23	14^{B}	25	$^{B}6$	19^{B}	18	$^{B}16^{B}$	14^{B}	12^{B}	13	10^{B}				170	170
B 8008	EBFPA	MAR. 28	194		8	25	22	5	15	25	$^{B}15^{B}$	15^{B}	15^{B}	$^{B}7$	$^{B}13$	$^{B}9$	$^{B}6$	7	190	197
B 2885	EBFPQ	MAR. 31	182	1	27	18		17	21	22	25	25	$^{B}9$	20^{B}					185	185
8751	EBSCA	MAY 7	193			11	10^{B}	17	$^{B}11$	12^{B}	16^{B}	12^{B}	12^{B}	11	9	$^{B}0$	4		135	135
B 2185	EBSCQ	MAY 3	197			2	18	16	16	20	17	9^{B}	10^{B}	8	$^{B}3$	13^{B}			132	132
B 2907	EBSPA	MAR. 31	190		4		12	18	15	8	14	17^{B}	21	19	$^{B}7$	11	11		150	150
B 4512	EBSPQ	MAY 5	189			8	19		15	$^{B}11$	$^{B}9$	$^{B}1$	$^{B}3$	5^{B}					81	81

B8080	LNFCA	MAR 28	217		1	20	22	19	19	22	22	25	25	24	26	20	17		262	262
B9028	LNFCQ	APR 25	221				23	22	15	22	22	26	24	23	14				191	191
B8105	LNFPA	MAR 28	221			20	23	4	21	24	27	28	22	24	22	19	14		248	248
B9027	LNFPQ	APR 25	217			2	6	25	21	26	27	29	22	24	14				196	196
B587	LNSCA	APR 1	248				17	17	15	15	17	17	1	16	1	18	10		144	144
8087	LNSCQ	APR 9	217			8	19	15	13	14	10	12		6	2				99	99
B63	LNSPA	MAR 18	203		14	19	5		7	10	16	19	15	19	20	16	2		162	162
B3089	LNSPQ	APR 7	292					1	5	10	18	10	3						47	47
119	LBFCA	MAR 23	246			5	26	24	25	27	19^B	15^B	14	^{B}13	^{B}14	^{B}14^B	12		208	208
B4082	LBFCQ	APR 28	240				5	24	24	24	^{B}20	^{B}16	^{B}14	^{B}13	^{B}10	^{B}8			158	158
7918	LBFPA	APR 2	226			1	14	25	2	22	28	^{B}15^B	6^B	10^B	9	5	11		148	148
B2818	LBFPQ	MAR 31	234			8	17		11	28	25	25	24	13	20^B				171	171
803	LBSCA	APR 27	228				14	15	14	15	11^B	9^B	7	^{B}4		6	10		105	105
8602	LBSCQ	APR 30	227				13	17	17	13	15^B	16^B	13	^{B}	19				123	123
7697	LBSPA	MAR 19	268				6	19	3	12	16^B	^{B}6	^{B}9	9^B	17	4	8		119	119
8941	LBSPQ	MAY 14	254					4	3	19	12^B	6^B	7^B						51	51
B1209	LNS-Q	APR 22	274					1	1		1		2		2	2			9	9
B1202		APR 22																	0	0

Legend: E, early (laid before 201 days of age); B, broody; F, fast (usually laid at the rate of more than 21 eggs per month); P, winter pause of ten or more days; A, persistent (continued production later than September 30); L, late (laid after 200 days of age); N, not broody; S, slow (usually laid less than 22 eggs per month); C, continuous (no winter pause); Q, quitter (stopped laying before October 1). Classification of broody birds in respect to rate is based on the non-broody months. For certain combinations it has not been possible to find records that fit the definitions closely in all respects. The horizontal lines indicate periods over which production extended; a pause of ten or more days is shown by a break in the line; B above the break indicates a broody pause. Under the heading Total is given the production for the biological laying year, which sometimes exceeds the 365-day year.

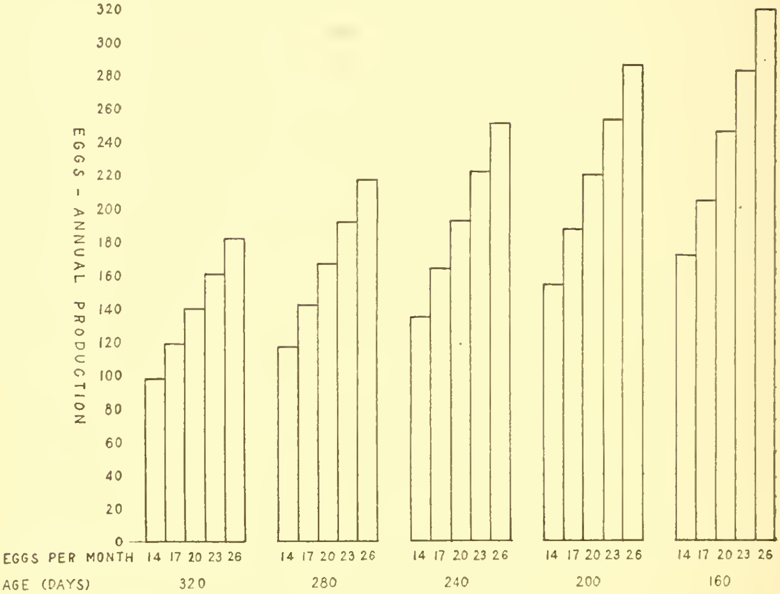

Fig. 2. — The Effect of Variation in Two Factors.

Five points of maturity and rate are chosen, and it is assumed that each bird was hatched April 15, was non-broody, was without winter pause and stopped laying September 30.

record. Fig. 2 was made by choosing five points of the first and second characteristics (maturity and rate), assuming that the other three remain unchanged, and showing by artificial records what would be the resulting yearly production. If all the variations of all the characteristics were combined in all possible ways, the number of different egg records secured would be in the thousands.[1] Environment is also responsible for much variation in production.

If the records of the highest producing hens are examined, it is to be noted that they begin early in life (and also fairly early in the season) and continue at a steady and relatively high rate throughout the twelve months. Examined from the negative standpoint, it is noticed that there are no broody pauses, no winter pause, no delay in beginning production, no early cessation of production, no slow rate while laying. A record at the low end of the series is zero, but one only shortly removed shows late maturity, early cessation and slow rate. The problem of the breeder, then, is to devise a method of eliminating the undesirable characteristics from the flock and of securing fairly uniform high production.

[1] It is a point of considerable importance to recognize that the greatest complexity occurs in those records near the mode of the egg production curve, and that those records near each extreme are less complex, so that studies made on a flock composed of either very high or very low producing birds will be simpler than if made on flocks of average production.

As long as attention is fixed solely on the number of eggs laid, and no recognition given to the fact that the difference between a 150-egg hen and a 200-egg hen is something more than just 50 eggs, progress in getting at the fundamentals of the inheritance of egg production is hindered. The solution of the problem demands that the inheritance of each component be ascertained by specially planned experiments. This would require about fifty years of one man's time, with a flock of 500 pullets trapnested through their first laying year.

The policy which was therefore adopted at this station was, using as a working theory the concept of an egg record as briefly outlined above, to establish a high-producing strain by improving the flock step by step, making it fairly homogeneous for one of the five characteristics and then for another. In this way there would eventually be built up a flock which would meet the standards required for the highest production. At the same time it was planned to make an intensive study of broodiness and to collect data on the other characteristics, with the purpose of gaining as much useful information as possible.

Plan of Procedure.

The Foundation Stocks.

The foundation stock as a whole proved deficient in desirable characteristics. The birds were late maturing and, when hatched in April or May, did not begin laying till midwinter. Many stopped producing by midsummer or soon after. The winter pause was present but not conspicuous because of the late start made. Rate of production while laying was excellent. The birds were deficient in vitality and were poor breeders. It was essential, of course, to remedy these last two defects before further work could be done. Stock of good vitality was added, but unfortunately the general satisfactory rate of production was lost and the winter pause accentuated, so that, as the next paragraph shows, ground was lost for the time being. (See Fig. 5, p. 109.)

The members of the flock hatched in 1915 were, on the whole, late maturing and broody, and exhibited a well-marked winter pause in early layers, a slow rate, and a tendency to stop production early in the summer. There were, however, individuals which matured early, others that were not broody, some that laid at a high rate, some that persisted in production till late fall, and some that lacked a winter pause. Individuals exhibiting various combinations of these characteristics also occurred, but there were none in which all the desired characteristics were combined. This was to be accomplished by breeding, and the present plan of procedure, vaguely formulated the year before, was put into active practice.

Basis of Selection of Breeding Females.

Beginning in 1916, female breeders were selected primarily for early maturity, and late maturing individuals used only when exceptional in other respects. A fair approach to the objective was obtained in the laying flock of 1917–18, partly through a fortunate nick between a single pair.

Meanwhile, the intensive work on broodiness had given a flock comparatively free from broodiness, so that it was known that broodiness could be very much reduced even if not eliminated. The next step was an attempt to fuse the low-broody strain, which were poor producers, with the early maturing line, which were good layers, by choosing non-broodies from the latter and good layers from the former. Of course, it was expected that the fusion would result in a temporary setback. The first year after the fusion, 1919–20, fewer eggs were laid and more broody birds occurred in the combined flocks than in the respective contributing strains, but this difficulty has been overcome. On reviewing the situation, it is clear that the desired objective would have been reached had the non-broody members of the high line alone been used, for these birds are the ones that constitute the major portion of the ancestry of to-day's flock.

While concentrating on maturity and broodiness, some progress has been made in eliminating the winter pause, and in securing larger numbers of birds that lay at a high rate. Data covering these statements are given in later sections of the paper. The proportion of birds in the flock that approach the desired type is much greater. With the increase in the number of birds approaching the desired type, birds with records that would have qualified them for breeders in the early stages of the work are now rejected. The basis of selection has been progressively altered and selection made progressively more stringent, as shown in Fig. 3 and Table I.

TABLE I. — *Data on the Mothers of the Several Flocks.*

Mothers of Pullets Hatched in —	Mean Age at First Egg.		Mean Winter Production.		Mean Annual Production.	
	Number of Birds.	Days.	Number of Birds.	Eggs.	Number of Birds.	Eggs.
1913	–	–	72	26.72	42	123.52
1914	36	252.89	59	40.17	49	141.02
1915	89	253.45	118	29.07	92	122.62
1916	60	228.60	61	47.38	57	147.72
1917	40	198.93	39	76.18	36	186.36
1918	25	193.08	25	92.76	22	204.41
1919	29	199.79	29	85.69	28	222.68
1920	38	197.71	37	84.78	16	228.06

In each case those mothers only are included having daughters with a corresponding record. Because of the clean-up in June, 1920, an exception is made so that the annual production for 1919 is for birds having daughters that laid up to June 1. For the first four years birds of the original stock whose hatching date is unknown were used in decreasing numbers as breeders, which accounts for the small number of birds whose mean age at first egg is given.

Other qualifications besides those exhibited in the egg records are required. A hen is a good breeder only if she produces such a number of pullets that they constitute a satisfactory index of her capacity (with a given mate) to transmit her own good laying qualities. Small families are undesirable, because they are often an inadequate sample of a bird's real breeding quality. As soon as it appears that a breeder's eggs are not hatching well, she is taken from the breeding pen and her offspring discarded. A few breeders are discarded for other defects, such as low vitality of their progeny.

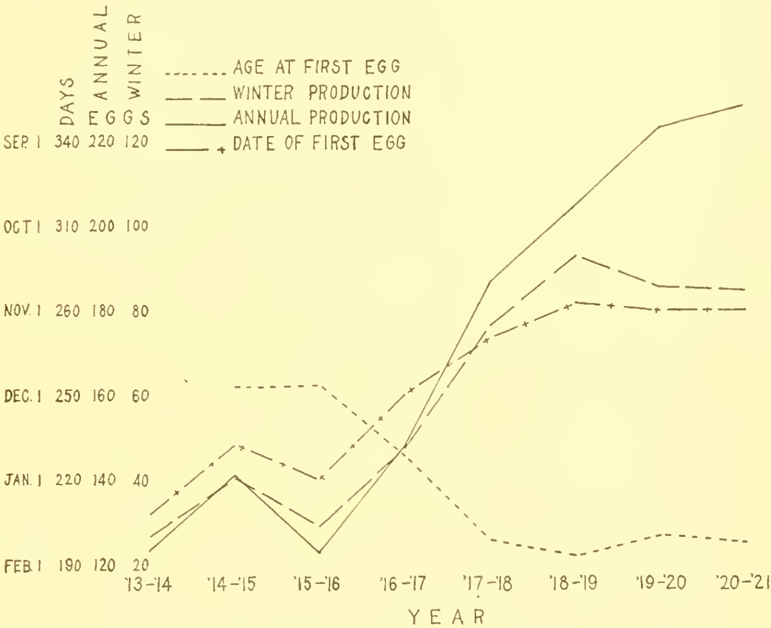

FIG. 3. — Mean Production of Female Breeders.
(From data given in Table I.)

Basis of Selection of Breeding Males.

The selection of suitable males is quite simple. First, each one comes from a large family and is the strongest, the most vigorous and usually the largest member of the group; second, he comes from a good mother; and third, the most important point of all, his sisters must have made good records.[1] The family which produces the largest proportion of females capable of qualifying as breeders is the first choice for one or more males. Naturally, males will be chosen from several families and always such as stand highest in desired characteristics.

[1] This involves keeping one or more representatives of each family till his sisters' records are available.

Continued Use of Breeders on the Basis of the Performance of their Offspring.

Birds used as breeders are kept till the records of their progeny are at hand. Many fail to transmit the desired qualities, either wholly or to a sufficient number of their progeny, and therefore are discarded. Exceptions are sometimes made with females that are otherwise remarkable, in the hope that they may nick better with another mate. Those birds that show pronounced ability in producing offspring that make egg records of the desired type may be bred several years in succession. The importance of a very few birds of this sort cannot be too greatly emphasized, for through these progress is made.

Points in Management that affect the Results.

A few points in the handling of the flocks need especial emphasis, as they bear directly on the interpretation of the results.

Flock Number. — Throughout these experiments the pullets have been kept in relatively large flocks, 100 to 125, while making their records, with the following exceptions: in 1912–13 there were two pens of 72 birds each; in 1913–14 there was one pen of 72 birds and several smaller groups of 25 to 35 each; in 1914–15 the pedigreed pullets were in large flocks, but the new stock was in smaller groups. The latter are excluded from the averages. Some years the high-line birds, or part of them, have been penned by themselves; other years they have been scattered through the flock. They have received exactly the same treatment that was given the rest.

The selection of the pullets that are put into the laying pens is based on the family. The best families having been decided upon, all the daughters in those families are included except those of exceedingly poor vitality, amounting to less than 5 per cent. As far as possible, families (offspring of one mother) containing fewer than seven daughters each are excluded. This has been done in order to enable a fair judgment of the breeding ability of any mother to be made. An exception was made to this rule in 1920–21, when all daughters weighing less than 3 pounds 6 ounces at four months of age were excluded. The effect of such exclusion, if any, on egg production is slight, as shown by correlation tables.

The time of year in which a flock of birds is hatched is one of the most important factors in determining the number of eggs laid. This is illustrated in several figures and tables, of which Fig. 13 (page 117) may be especially cited. Note that the late hatched flock loses about two months' production, — a production that, as far as the records show, is not compensated for, except in slight measure, at other seasons.

It is the practice at this station to hatch weekly. The length of the hatching season has varied from year to year, but, unless otherwise stated, only records made by birds hatched between March 25 and May 14, inclusive, are presented in this paper. The mean hatching date is April 18, from which the several yearly means vary little as shown by Table II.

TABLE II. — *Data on the Flocks of 1912–20.*

PULLET YEAR.	Hatching Date.[1]		Date of First Egg.		Age at First Egg.			Winter Production.			Annual Production.		
	Mean.	Change from 1913 (Days).	Mean.	Change from 1912 (Days).	Number of Birds.	Mean Number of Days.	Change from 1913 (Days).	Number of Birds.	Mean Number of Eggs.	Change from 1912 (Eggs).	Number of Birds.	Mean Number of Eggs.	Change from 1912 (Eggs).
1912–13	–[2]	–	Jan. 19	0	–	–[2]	–	138	28.39[3]	0.00	123	114.38[3]	0.00
1913–14	Apr. 19	0	Dec. 31	—19	168[4]	255.61	0.00	171	36.44	+8.05	171	123.64[5]	+9.26
1914–15	Apr. 19	0	Jan. 26	+7	115	282.80	+27.00	113	13.27	—15.12	80	103.25	—11.13
1915–16	Apr. 18	—1	Jan. 7	—12	224	264.27	+8.66	237	29.44	+1.05	208	121.70	+7.32
1916–17	Apr. 19	0	Dec. 5	—45	329	229.71	—25.90	328	42.46	+14.07	294	133.67	+19.29
1917–18	Apr. 17	—2	Nov. 16	—64	291	212.96	—42.65	280	59.40	+31.01	237	165.85	+51.47
1918–19	Apr. 19	0	Oct. 30	—81	141	194.44	—61.17	109	63.45	+35.06	64	169.19	+54.81
1919–20	Apr. 20	+1	Nov. 18	—62	157	212.04	—43.57	124	58.23	+29.84	–[6]	–[6]	–[6]
1920–21	Apr. 12	—7	Oct. 29	—82	168	199.99	—55.62	160	67.65	+39.26	109	199.73	+85.35

[1] Mean hatching date based on birds that completed the winter.

[2] Mean hatching date and mean age at first egg not known for 1912.

[3] Five eggs arbitrarily added as November's quota, since trapnesting was not begun until December.

[4] Is less than 171 because of birds that never laid; kept through winter but not through year.

[5] Because of limited facilities, only 59 birds in 1913–14, hatched between the limiting dates, were trapped throughout the year. They were a selected group with an average winter production of 41.92 eggs against 36.44 for the entire flock, which, therefore, has a probable mean annual production of 123.64 eggs.

[6] Records stopped June 1. See p. 108.

Successive years do not represent successive generations. The later years include the offspring of selected parents belonging to several generations.

Floor eggs are excluded from all the data used in this paper. Artificial lighting has not been used.

Because of the prevalence of disease, the whole plant, both college and experimental, was given a thorough cleaning during the summer of 1920. All adult birds were disposed of June 1, so there are no annual records for that year.

Seasons at which Increased Production is most Desirable.

The average well-cared-for flock of pullets of American breeds begins production some time in late fall or early winter, reaches its maximum

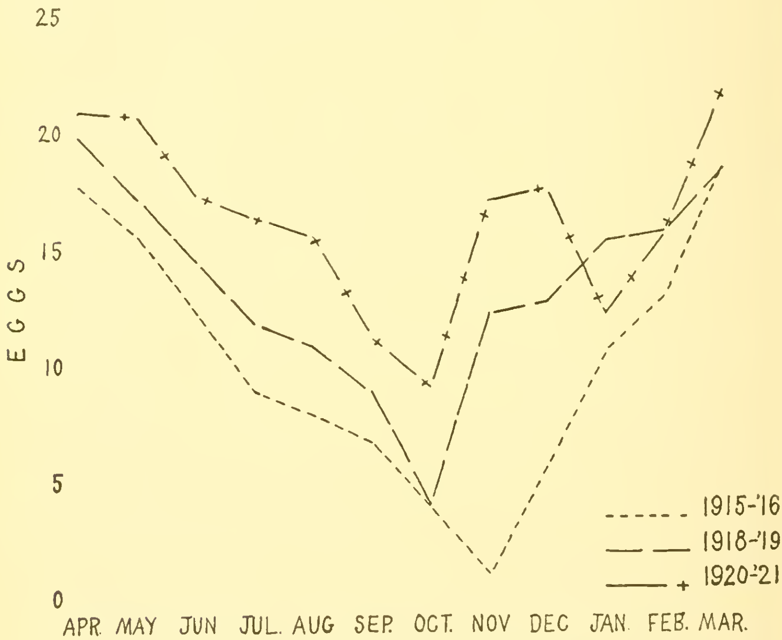

Fig. 4. — Seasonal Distribution of Production.

The right-hand part of the curve beginning with November precedes, chronologically, the left-hand portion. This arrangement emphasizes lack of production in certain months.

in March or April, and then declines more or less rapidly toward zero the following autumn, as represented in Fig. 4. The curve starts at the high point in April and ends at the high point in the preceding March, instead of starting with the beginning of production, as is customary. This arrangement emphasizes the hollow between the two high points. It is clear that if good production can be obtained in October, November and

December it should not be hard to improve production in other months, where necessary. Hence, emphasis is laid on winter production, so called, as at this season eggs bring two to two and one-half times the price paid in April. The producer who can secure a 50 per cent yield in those months will reap the reward due to his ability, at least in the immediate future, while if the methods by which such a yield is obtained become common practice, the consumer will benefit through lower prices and steady supply. While the producer may not continue to reap the harvest due to pioneer methods, his business will be on a firm basis, with the period of all outgo and no income eliminated.

The desirability of increased fall and winter production is made clearer by a comparison of the station flocks with certain farm contest flocks in Missouri as reported by Townsley (1920). The latter's average November production for the last four years ranges from 2.0 to 2.5 per hen, being 2.3 eggs each for nearly 25,000 birds in 1920. The best flock of 124 birds averaged 8.1 eggs each. On the other hand, a flock of high-line birds of similar size at this station averaged 18 eggs each. If all the flocks of the country were as good layers as this particular flock, — and there is no biological reason why they should not be, — it is apparent that both consumer and producer would benefit.

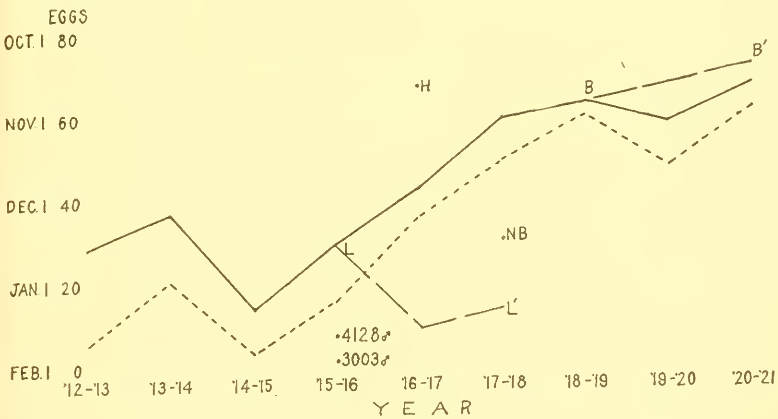

Fig. 5. — Winter Production and Date of First Egg for Flocks of 1912–20.

Solid line represents mean winter production. Up to but not including 1917–18, the mean for the entire flock is given. From 1917–18 on, it is for the high line only. L–L′, low line. B–B′, original high line. H, mean of several high families in 1916–17. NB, mean of low-broody flock. 4128♂ and 3003♂, mean of daughters of the respective males.

Dotted line represents mean date of first egg for set of birds making winter records shown in continuous line.

Results secured.

Data on mean winter production, mean annual production, and mean age at first egg are presented for each year of the experiment. Data on broodiness have been recently published and need not be repeated here.

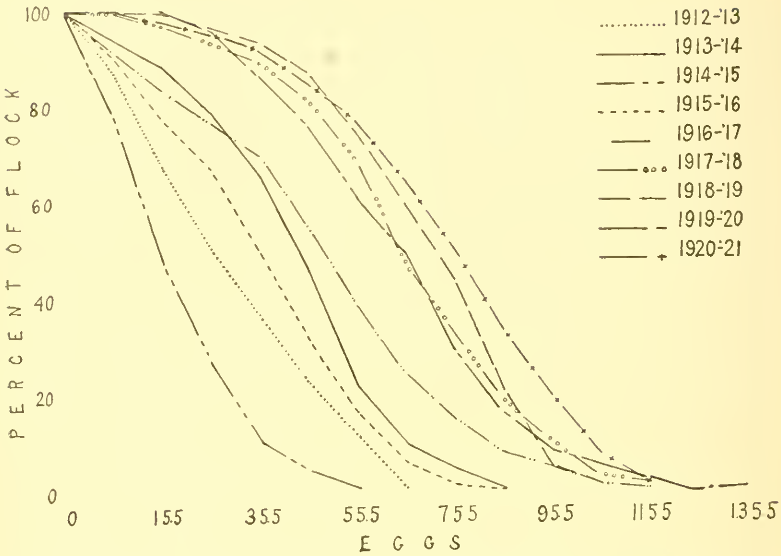

FIG. 6.—Integral Curves showing the Percentage of Each Flock having a Winter Egg Production as Great as that indicated, or Greater.

No allowance made for November in 1912. (See Table II.)

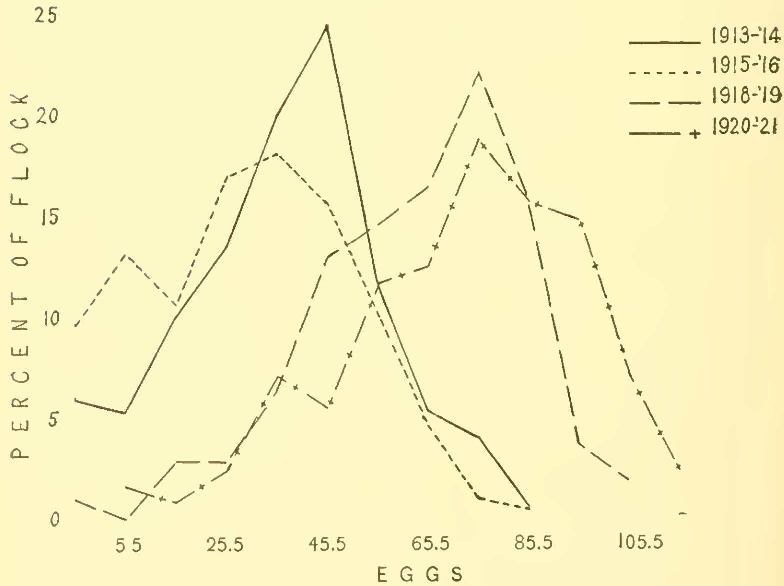

FIG. 7.—Frequency Polygons showing the Percentages of Flocks having Winter Production indicated.

1920–21 curve is for the original high line only.

Data on the initial cycle, winter pause, spring production, summer production, date of last egg and rate of production are restricted to certain years, because breeding for changes in these characteristics has necessarily been secondary. They indicate clearly such changes as have occurred. For purposes of clarity, intermediate years are omitted in certain graphs.

Changes in Mean Winter Egg Production.

Winter egg production is defined as the number of eggs laid prior to March 1 in the first laying (pullet) year. In Table II, represented graphically in Fig. 5, is given the mean winter production of the flocks from 1912 to 1920, inclusive. A high-line strain, as a definite entity, was not propagated until 1917. From 1917 on, the winter production given in the table and graph is that of the high line. A low line, L–L [1], Fig. 5, was propagated in a small way for a time, but finally lost. In 1917 a point is indicated for comparison with the high line which is the weighted production of a flock bred primarily for absence of broodiness, and in whose establishment all non-broodies available, high producers or low, were mated with three males: No. 3003; his son, No. 5470, by his sister; and his grandson, sired by No. 5470 out of an unrelated bird with a good record. The sisters of No. 3003 were noted for very low production in addition to non-broodiness. The average winter egg production of the daughters of No. 3003, as well as of the daughters of No. 4128, another low male of separate origin, is indicated for further comparison.

Graphic representation of the improvement made is shown by integral curves for each year as given in Fig. 6, while frequency polygons for winter egg production for certain years are given in Fig. 7, the statistical constants being given in Table III.

TABLE III. — *Statistical Constants for Certain of the Flocks.*

WINTER EGG PRODUCTION.

Year.	Number of Birds.	Mean.[1]	Standard Deviation.	Coefficient of Variation.
1913–14	171	36.70± .88	17.05± .62	46.45±2.03
1915–16	237	29.86± .76	17.40± .54	58.27±2.34
1918–19	109	63.61±1.27	19.62± .90	30.85±1.54
1919–20	124	58.56±1.45	23.93±1.02	40.87±2.02
1920–21	160	67.34±1.33	24.88± .94	36.94±1.57

ANNUAL EGG PRODUCTION.

Year.	Number of Birds.	Mean.[1]	Standard Deviation.	Coefficient of Variation.
1913–14	59	145.41±3.04	34.66±2.15	41.06±2.95
1915–16	211	121.21±1.87	40.20±1.32	33.17±1.20
1918–19	64	170.02±2.52	29.89±1.78	43.31±3.03
1920–21	109	200.98±2.57	39.78±1.82	33.15±1.67

[1] Means calculated from grouped data instead of ungrouped as in Table II.

TABLE III. — *Statistical Constants for Certain of the Flocks* — Concluded.

AGE AT FIRST EGG (DAYS).

YEAR.	Number of Birds.	Mean.[1]	Standard Deviation.	Coefficient of Variation.
1913–14	168	255.62±1.13	21.68± .80	48.60±2.17
1915–16	243	263.69±1.50	34.61±1.06	47.61±1.76
1918–19	141	194.58±1.38	24.23± .97	55.60±2.84
1920–21	168	200.44±1.38	26.50± .98	53.61±2.48

[1] Means calculated from grouped data instead of ungrouped as in Table II.

In Fig. 8 certain changes in winter production of selected groups are given, comprising, first, the highest record made in each season by any one individual; second, the best average record made by the daughters of any one mother, provided not less than five daughters comprised the

FIG. 8. — Winter Production.

Broken line, best individual; solid line, best average made by daughters of one female; dotted line, best average made by daughters of one male.

group; and third, the best average record made by the daughters of any one male for each season, provided that he had ten or more daughters.

Changes in Mean Annual Production.

Annual production is the number of eggs laid in the first laying year, beginning with the first egg and running 365 days therefrom. Barring longevity, it is probably the best index of a bird's innate laying capacity.

Reasons for this view have been presented elsewhere. In Table II and Fig. 9 are given the data showing the changes that have taken place. The statements regarding the flocks, as given for winter production, apply here also.

The integral curves for each year will be found in Fig. 10; frequency polygons are given in Fig. 11, the constants in Table III.

Changes in Daily Winter Production.

The daily flow of eggs is a matter of some importance to the commercial poultryman, because of market fluctuations in price. Daily production curves illustrating this flow show some points not brought out in curves plotted on larger time units. The labor of compiling such curves is great, however, unless birds are penned in such a way that the pen record can be used. A few such pen records have been studied and are shown in Figs. 12 and 13 (see pages 116 and 117).

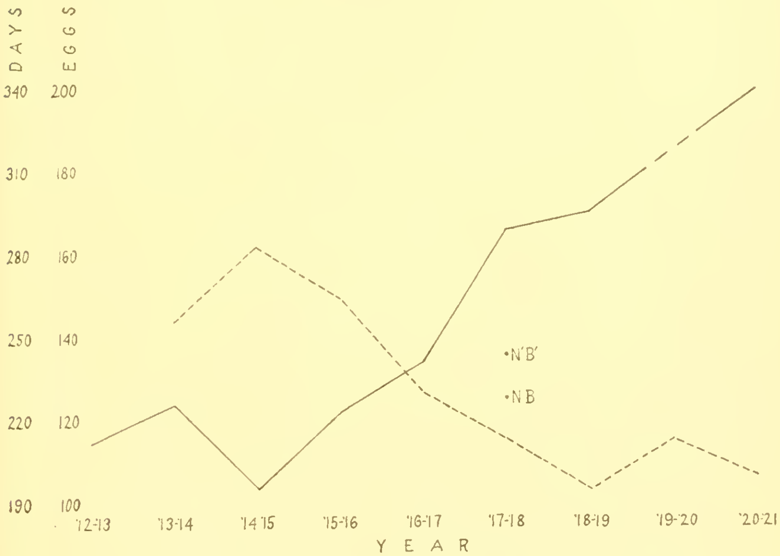

FIG. 9. — Mean Annual Production (Solid Line) and Mean Age at First Egg (Dotted Line).

NB, mean annual production, and N' B', mean age at first egg, for low-broody flock. No annual record for 1919–20. (See page 108.)

The points in all curves calling for particular attention are: the marked irregularity in number of eggs laid on consecutive days; the occurrence of waves of several sorts; the angle of slope of the curve at the beginning of production; the sharp descent from the maximum, due to the winter pause, in the curves of early hatched flocks, and the more gradual rise on recovery, with the marked rise in the curve toward the end of February. The later hatched layers do not exhibit such a sharp decline due to the winter pause. The amount is less and recovery quicker.

Changes in Age at which First Egg is laid.

Early in the history of these experiments it became evident that, on the average, those birds that laid the largest number of eggs before March 1 were those that began laying first. As the average age at which the first egg was laid was eight months, it was evident that either the pullets must be hatched early to get them mature early in the fall, or else they must grow and develop faster. Early maturity, therefore, was made the chief aim of the breeding program, with the results shown in Table II and Fig. 9. Changes in mean date of first egg, Fig. 5, vary directly with changes in mean age at first egg. Integral curves are given in Fig. 14, frequency polygons in Fig. 15 (page 119), and their constants in Table III. Note that

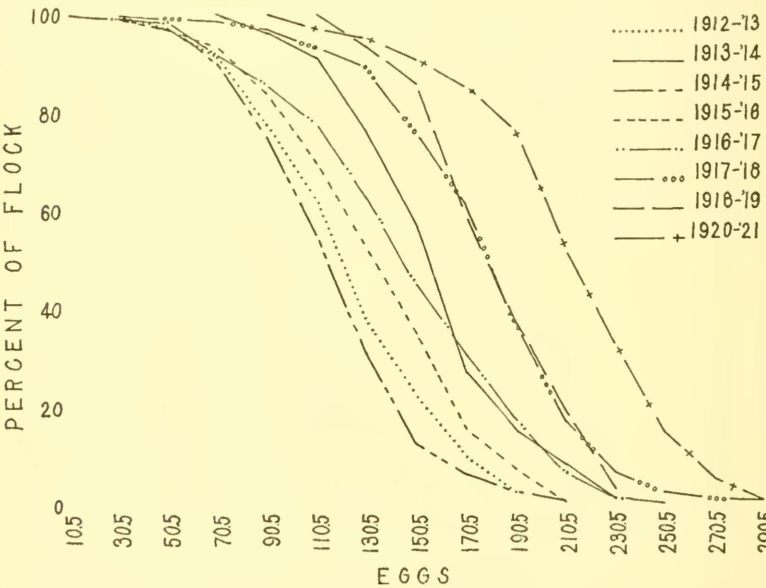

FIG. 10. — Integral Curves showing the Percentage of Each Flock having an Annual Production as Great as that indicated, or Greater.

One zero in 1917–18 is not shown. In 1912–13 no allowance is made for November production as in Table II. The curve for 1913–14 is that of the 59 birds kept through the year. (See Table II.)

apparently something more than a sifting out of an early maturing strain has occurred, as indicated by the mean and range for 1918–19, Fig. 15.

Earlier maturity uncovered, or at least was associated with, more evidence of the winter pause than appeared earlier, so that the gain in production was not as great as was anticipated. As indicated below, progress is being made in reducing the length of the pause, so that, eventually, continuous production throughout the winter is expected.

Since 1917 no attempt has been made to lower the age at first egg. The basis of selection has been the same in each year since 1917. (See

Table I and Fig. 3.) Although there is a fascinating problem involved in attempting further selection for earlier maturity, such an endeavor is not consonant with the main project.

Changes in Length of the Initial Cycle and its Complement, the Winter Pause.

In the station strain of Rhode Island Reds, many individuals produce an initial series of eggs which is followed by a rest period, the winter pause. The trait does not lend itself to ordinary statistical treatment because of its nature, which depends partly on an inherent condition of the strain, and partly on environmental conditions, particularly those

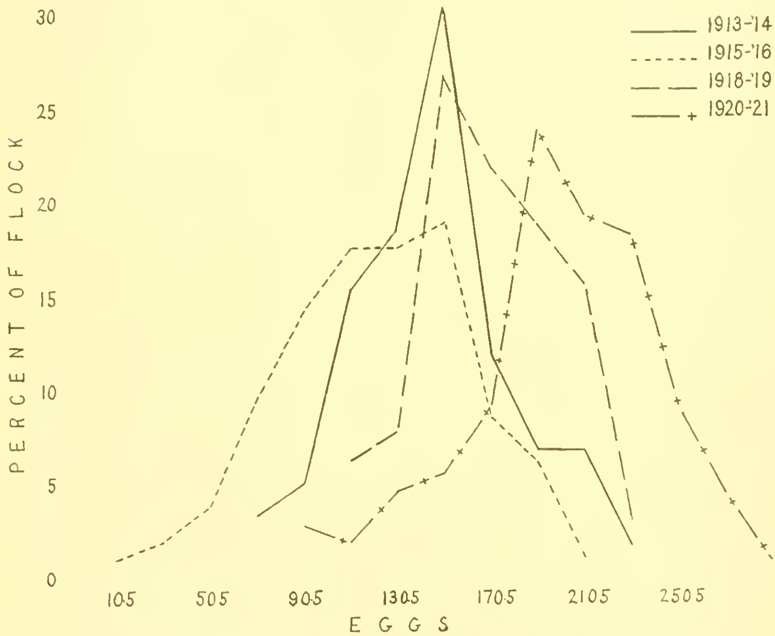

FIG. 11. — Frequency Polygons showing the Percentages of Flocks laying the Given Number of Eggs per Year.

The curve for 1913-14 is that of the 59 birds kept through the year. (See Table II.)

that determine the time of year when the birds begin to lay. Further, it is possible that more than one cycle is involved. The present discussion, therefore, is limited to a general descriptive treatment of the subject, based on experiences with flocks subsequent to those studied in an earlier paper (Goodale, 1918).

It is now clear that the earlier a pullet begins to lay in the autumn, the more likely she is to exhibit the winter pause. A few early layers, however, go through the entire winter without pausing. Roughly speaking, 90 per cent of pullets laying their first egg early in the season (September) exhibit the pause, in contrast to only 30 per cent of those beginning late in the season (December). It is possible that the appearance of the pause is due to some direct effect of the season (length of days, for instance), but since there is no uniformity in the length of the egg-laying period, and since one member of a flock may begin the second laying period at the same moment another is finishing the first, it is clear that whatever influence the environment may exert is secondary, the primary cause being a change in the physiological condition of the layers, expressed in some individuals by an actual pause, in others by a slowing down in production, while in a few individuals no external effect becomes apparent. Note, as shown in Fig. 13, that a flock of late-hatched pullets were laying at a high level at the same time that their early-hatched sisters were in a slump. Clearly it is not the environment alone that is responsible for the pause. Some observations lead to the belief that environmental conditions which

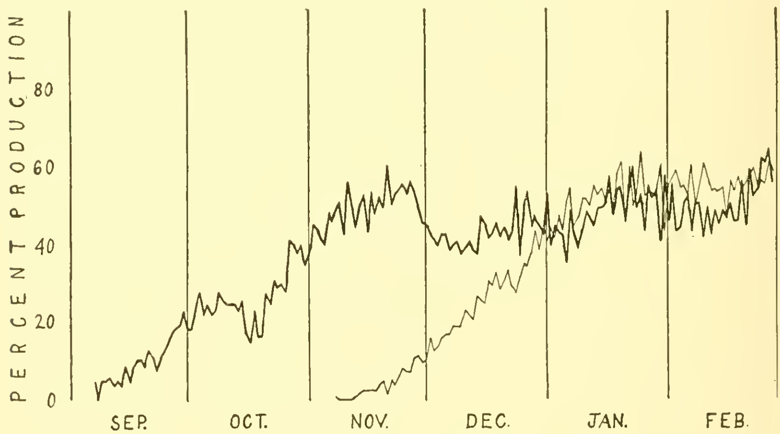

Fig. 12. — Daily Production.
Heavy line 1917–18, Pen III; light line 1913–14. (See text for details.)

at other times would not stop production may do so in this sensitive physiological state. Given an initial (winter) cycle of variable length, it is apparent that in some individuals it may extend into early spring and either overlap the spring cycle and thus fail to become apparent, or perhaps, because of a direct stimulus due to longer days, production may be kept up, and thus the winter pause is suppressed in pullets beginning to lay late in the season.

As far as possible, selection has been directed against the winter pause, and while not eliminated, there is evidence that its length has decreased, and, correspondingly, the length of the initial period increased. This is shown in Fig. 13, where a high production over a period of six weeks was maintained, which is much longer than three years previously, as seen in Fig. 12. The average number of eggs laid, prior to the pause, was 12 more in 1920 than in 1917.

Changes in Amount of Broodiness.

This phase of breeding for increased egg production has been discussed in another place (Goodale, 1920). Here it is sufficient to recall that, while some birds lay continuously throughout spring and summer without any marked slowing in rate of production, others lose much time on account of broodiness, — a loss that very clearly is *not* compensated for.

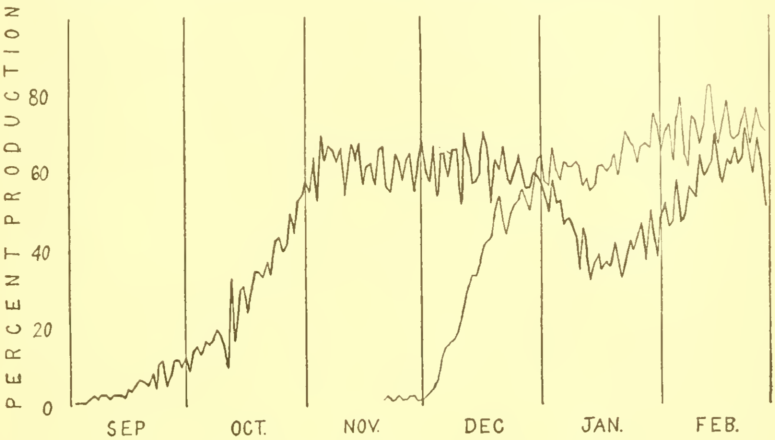

FIG. 13. — Daily Production of Two Pens of the Same Breeding, 1920–21.
Heavy line, April hatched; light line, late hatched.

NOTE. — The records of this flock were made under quite different conditions and methods of management from those made by the other flocks. *A priori*, they appeared to be considerably sub-optimal, but the results show that they were at once correct and simple. A brief description of the conditions and methods of management follow.

The 50 females and 6 males were in a pen 22 by 11, 6 feet high at the plate and 10 at the ridgepole, made by stretching wire netting across the south side of a second-story barn floor. A windbreak of paper extended 3 feet from the floor. Roosts were at the west. The main opening was a pitch hole about 4 feet square in the south side. Additional light came from a window 2 feet square in the gable, plus some light from two openings in other parts of the loft. A little sand was put on the floor and straw used as a litter. The birds had water and open boxes of dry mash constantly before them. Oyster shell was fed on the floor. No special grit was fed. Three to 4 pounds of cracked corn were fed in the morning, and double that amount at noon. *Green* sprouted oats *ad libitum* (165 square inches) were fed at noon. Droppings accumulated on the floor back of a wire litter stop. Besides gathering the eggs and keeping straw in the nests and the litter distributed (the latter mostly done by feeding the cracked corn where it was thickest), no other attention was given. The caretaker was away during the day.

The loss due to broodiness is shown when the seasonal production of a broody race is compared with that of a non-broody race. The maximum production of a broody flock comes in March. April is nearly as high, but during May and June, corresponding to the period of progressive increase in the number of broody birds, production declines sharply to a level that either remains nearly constant for July, August and September, or in which the descent is much less marked. (See Fig. 4, 1915–16 and

1918–19.) The highline flock of 1916–17 averaged 105 eggs during the six non-broody months, November to April, while for the six broody months following, May to October, the average was only 70 eggs. Leghorns, on the other hand, continue production at a relatively high level all summer, and first decline sharply in early fall. Kirkpatrick and Card (1917) give data showing a parallelism between degrees of non-broodiness and summer production. The several races, viz., Rocks, Wyandottes, Reds and Leghorns, lay nearly the same number of eggs per bird in March and April and do not differ much in production prior to this date. But during May, June, July, August and September the Leghorns, having the smallest amount of broodiness, lay much more heavily than the other breeds, while the Reds, the most broody race, give the poorest summer production. The Rocks and Wyandottes, which are very much alike in amount of broodiness and intermediate between the Leghorns and Reds, are much alike in their summer production which is intermediate between that of the Reds and Leghorns.

A striking illustration of the loss due to broodiness in an individual bird is shown by B8316, whose egg record is given in Fig. 16. If she had not become broody, but had instead continued to lay through June, July and August at the rate of 26.4 eggs (her average for the seven months preceding), her annual production would have been 306 eggs, 27 more than her actual record of 279 eggs. (The pause in September looks much like a broody period, but she did not stick to the nest, and therefore was not put in the broody coop.)

The first experiment in breeding out broodiness was successful, but at the expense of egg production (Goodale, 1920). The experiment in breeding broodiness out of the high line and still maintaining production is not yet complete, but gives promise of success.

Changes in Date of Last Egg.

The dates of last egg and of first egg determine the length of the annual period. The two limiting dates are treated separately, because it seems probable that date of last egg results from the action of some internal mechanism the nature of which is unknown. While practically all birds are laying from the middle of March to the middle of June, after this, one by one, the birds stop laying, not to resume until next season. The majority, however, continue production till the middle of September, the mean date of last egg being near October 1 in 1914 and 1919. Cessation of production has a genetic foundation, as is indicated by the behavior of various families in this respect, some stopping early and others late. Moreover, many of the best layers show a tendency to continue production indefinitely.

The lack of evidence that the average date of cessation of production has been advanced well into the fall may be associated with lack of especial effort to secure by breeding continued production late into the fall, — an effort that did not seem worth while till after broodiness had been bred out.

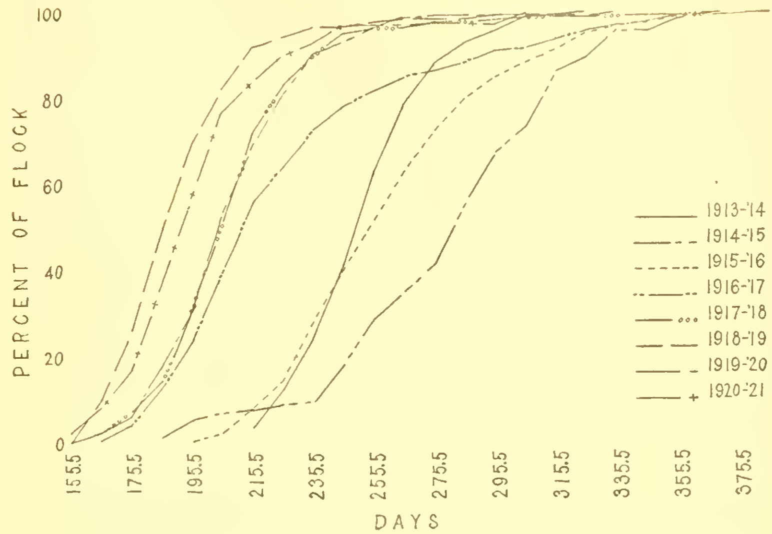

Fig. 14. — Integral Curves showing the Percentage of Each Flock beginning to lay at or before the Ages indicated.

One exceptionally old bird is omitted from 1915–16, and one from 1920–21.

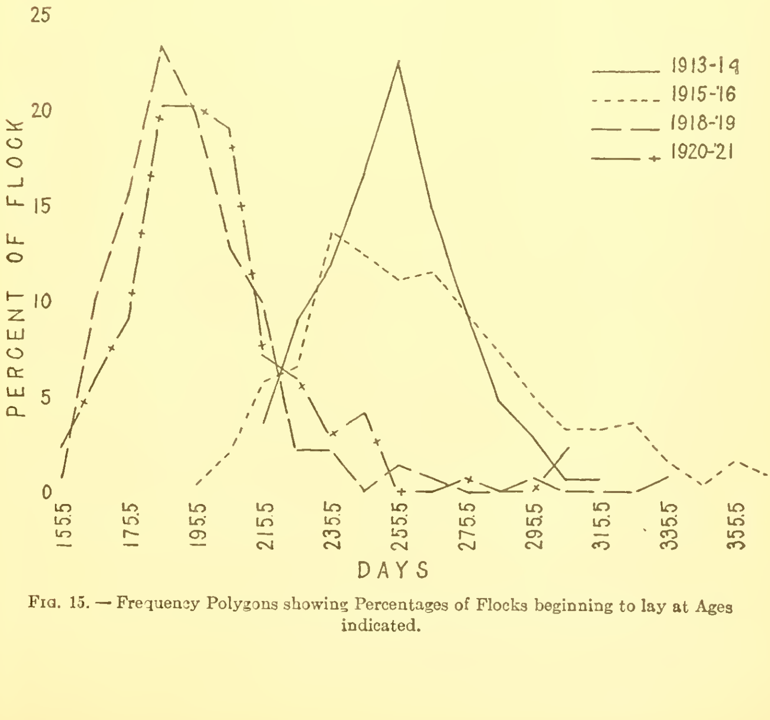

Fig. 15. — Frequency Polygons showing Percentages of Flocks beginning to lay at Ages indicated.

Changes in Rate (Intensity) of Production.

Rate or intensity of production is defined as the number of eggs laid per time unit measured in days. There are several possible time units, such as the month, the initial cycle, the inter-broody periods, the summer period and the spring period. Closely associated with this character is length of clutch, or number of days of continuous (daily) production. Units including well-defined rest periods, such as those due to broodiness or the winter pause, are specifically excluded.

While breeders have been selected, other desiderata permitting, on the basis of high monthly production during the winter, the heterogeneous condition of the flocks in respect to other characters makes comparisons unsatisfactory. The present discussion, therefore, is limited to a comparison of the highest production in any one calendar month before March 1. The use of the calendar month, instead of the highest production for a period of thirty or thirty-one days, although unsuitable in comparing individuals, is sufficiently satisfactory for comparison of flock averages. The average highest monthly production in 1913–14 was 19.28 eggs; in 1920–21 it was 21.10, showing an apparent gain of nearly 2 eggs.

Changes in Seasonal Distribution of Production.

It has been pointed out that the season at which increased production comes may be quite as important as an absolute increase. In addition to winter production, the year may be divided into spring, summer and fall, but differing from the calendar seasons.[1] Spring production includes March, April and May, chiefly because the station statistics show that, regardless of changes at other seasons, the average for these three months (Table IV) has remained nearly constant during these experiments. The period, moreover, is characterized by a sharp decline in mean monthly production from March (sometimes April) to June, due almost wholly to broodiness. A slight increase in mean production for this season has been noted with higher annual production.

[1] Other divisions might be made from the biological standpoint, but such divisions vary from flock to flock and with methods of breeding. The divisions used are approximate and somewhat arbitrary. Further, in studying seasonal distribution, the 365-day limit to a year has been disregarded.

NO. B8316 HATCHED APR. 4, 1920

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTAL
SEP.																																
OCT.																				I	I		I	I	I		I	I		I	I	9
NOV.	I	I	I	I	I	I		I	I	I	I	I		I	I	I	I		I	I	I	I		I	I		I	I		I		24
DEC.	I		I	I		I	I	I		I	I	I	I		I	I	I	I	I		I	I	I	I	I		I	I	I	I		24
JAN.	I	I	I	I		I		I	I	I	I	I	I	I		I	I	I	I	I	I	I	I	I	I	I	I	I		I	I	27
FEB.	I	I	I	I	I	I	I		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I				26
MAR.	I		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		I	I	I	I	29
APR.	I	I		I	I	I	I			I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		27
MAY	I	I	I	I	I	I	I	I	I	I		I	I	I	I		I	I	I	I	I		I	I	I	I	I	I	I	I	I	28
JUN.	I	I	I	I	I	I	I	I	I		B	R	O	O	D	Y	—						I	I	I	I	I	I	I			16
JUL.		I	I	I	I	I	I	I	I	I	I	I	I		B	R	O	O	D	Y					I	I	I	I	I	I	I	19
AUG.	I	I	I	I	I	I	I	I	I	I	I	I			B	R	O	O	D	Y	—	—				I	I	I	I		I	17
SEP.	I	I	I	I	I	I	I	I	I	I	I	I													I	I	I	I	I	I		18
OCT.	I			I	I	I	I	I	I	I	I	I	I	I	I	I	I															15
NOV.																																

YEAR'S TOTAL 279

Fig. 16. — Egg Record of a Hen, showing the Effect of Broodiness.

TABLE IV. — *Seasonal Distribution of Production.*

YEAR.	Mean Number of Eggs for —						
	November 1 to March 1.	March 1 to May 1.	March 1 to June 1.	November 1 to May 1.	May 1 to November 1.	June 1 to October 1.	Year, November 1 to November 1.
1912-13 . . .	28.73	34.54	50.66	63.27	50.98	34.86	114.25
1913-14 . . .	36.34	33.17	47.13	69.51	54.12	40.16	123.63
1915-16 . . .	30.40	36.24	51.79	66.64	55.16	39.61	121.80
1916-17 . . .	41.39	38.15	53.60	79.54	52.91	37.46	132.45
1917-18 . . .	55.95	37.90	52.96	93.85	68.96	53.90	162.81
1918-19 . . .	56.07	38.36	55.61	94.43	67.58	50.33	162.01
1919-20 . . .	51.07	34.90	50.50	85.97	–[1]	–[1]	–[1]
1920-21 . . .	62.34	42.65	63.30	104.99	90.37	60.67	195.36

[1] Records stopped June 1. See p. 108.

Summer production includes June, July, August and September. The sharp decline previously noted is checked, and the mean monthly production declines much more gradually from month to month till October. Some years the decline is less than others (see Table V). The decline during the summer is due to the completion of the annual cycle on the part of some individuals, the first cases occurring in June, and to some slackening in rate (intensity). As shown in Table IV, there has been some increase in summer production in the high line over the earlier years. It is believed that the elimination of broodiness will be the main factor in securing further increase of production during these months.

TABLE V. — *Decrease in Mean Monthly Production from Highest Monthly Mean (March or April) to June, and from June to September.*

YEAR.	Mean Production.					
	Greatest Monthly.	June.	Difference.	June.	September.	Difference.
1913-14	M. 17.17	10.75	6.42	10.75	7.74	3.01
1915-16	M. 18.56	12.26	6.30	12.26	6.67	5.59
1916-17	M. 19.41	10.62	8.79	10.62	6.98	3.64
1917-18	M. 20.66	13.28	7.38	13.28	10.69	2.59
1918-19	A. 19.78	14.56	5.22	14.56	8.86	5.70
Average for five years .	19.12	12.29	6.82	12.29	8.19	4.11

Fall production includes October, overlapping into the following months and thus the next calendar year. It is the season of completion of the annual cycle on the part of most individuals. There is a considerable tendency for the best layers to keep producing, and, as their numbers have increased, it has been reflected in somewhat higher average production during this period.

Changes in Variability.

As shown by both the standard deviation and the coefficient of variation[1] (Table III), and by the several frequency polygons (Figs. 7, 11 and 15) for winter egg production, annual production and age at first egg, there has been no especially significant lessening of variability as a result of selection. Selection has merely moved the frequency polygon to one side without changing its general character.

Influence of Changes in Sanitary Methods.

The work was commenced on the basis of the best poultry practices available, but the sanitary measures proved wholly inadequate, and suitable methods had to be developed. There are, however, sufficient checks, indicated especially in Fig. 5, which show, with the exceptions noted in the next paragraph, that fundamentally the changes in production are due to breeding.

The low mean production of 1912–13 is due in part to late hatching. Other factors can only be guessed at. The low production of 1914–15 is probably due to improper methods of brooding plus disease and poor help.

RECOMMENDATIONS.

It is difficult, at present, to lay down a series of recommendations that can be followed by breeders, with a guarantee that they will work in every case. The following recommendations, based on experience, are intended only for the man who is prepared to go to the necessary expense, time and trouble.

A. Prerequisites.
   1. Proper management, including housing, feed, sanitation.
   2. Maintenance of vigor. It is true, hens of poor vigor are sometimes good layers, but good vigor as a rule is essential.
   3. (*a*) Careful trapnest egg records.
      (*b*) Careful pedigree records.
   4. A good understanding of both desirable and undesirable egg production characteristics in the flock to be improved.
   5. Families of at least seven pullets.
   6. Pullets hatched between March 25 and May 15.

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[1] The coefficient of variation, if calculated according to the usual formula C. V. $= \frac{\sigma}{M} \times 100$, is a poor index of the real variability, since the range of the polygon does not begin at zero. It is obvious that the formula C. V. $= \frac{\sigma}{M-X} \times 100$, where X is the lower end of the range, is a better index of variability. This is the formula used for age at first egg and for annual production in Table III.

B. Method.

The flock is to be improved by degrees, taking one desirable character at a time and making sure that it is well established in the flock as a whole before concentrating on a second.

In order to be as specific as possible, the following detailed outline is given: —

First Step. — Get the flock so that the pullets will mature before 200 days of age, by choosing as breeders those that mature before that age. The males must be from hens of the same qualifications, or brothers to those families of pullets that give the greatest percentage of qualifying females.

Second Step. — Choose as breeders birds that mature right and which are not broody. This step is not necessary for Leghorns.

Third Step. — As soon as a sufficient percentage of the flock — say 50 per cent — qualifies in these two respects, make the breeders qualify in three characters. Require them to mature before 200 days of age; to be free from broodiness; and to lay 22 eggs in either November or December.

Fourth Step. — As soon as enough birds qualify, make the breeders qualify in still another point, so that the qualifications become: first egg before 200 days of age; not broody; 22 eggs in November or December; not less than 80 during the winter, and continuous production for at least twelve months. At this point, if the breeder so desires, egg size, color or other characters may be added to the qualifications required of breeders, or he may aim for still better production.

Only those females should be used a second time, at least with the same male, some of whose progeny make an advance over the parent, unless the family as a whole is better than the average of the preceding generation. On the other hand, any pairing that gives superior results may be repeated year after year, or until something better has been obtained.

It should be pointed out that the larger the flock trapnested, the more rapid should be the progress made, for with a flock of two to three thousand pullets under the trapnest, it should be possible to pick out 30 to 40 birds that when tested will give ten or fifteen breeders of proven ability. These, if properly handled, should make possible very rapid progress.

Summary.

1. A description of changes in various phases of egg production is given.

2. Both mean winter and mean annual egg production have increased.

3. The age at which the first egg is laid has been reduced.

4. Progress in eliminating both the winter pause and broodiness is shown.

5. Provisional recommendations for improving egg production by breeding are given.

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BULLETIN No. 212.

DEPARTMENT OF AGRICULTURE.

A THIRTY-YEAR FERTILIZER TEST.

BY SIDNEY B. HASKELL.

History of Plots.

In February of 1889 Dr. W. O. Atwater, then director of the Office of Experiment Stations of the United States Department of Agriculture, issued a call for a conference to consider and adopt if practicable a uniform method of conducting what were then called soil tests. As a result of this call a conference was held in Washington, this Station being represented by Professor Wm. P. Brooks. A method of testing the soil by means of comparative field plots was decided upon, and in Massachusetts a number of such tests were instituted. Two of these were on the Station grounds, — the South Soil Test started in 1889 and the North Soil Test in 1890. Nine similar tests were laid out in other parts of the State. The object was "to find out the particular fertilizer requirements of the soils of different localities;" and in the letter sent out arranging for the co-operative tests, the statement was made that "the best soil for the purpose is one which represents best the average conditions in your county, which is level or of uniform moderate slope, of uniform and low fertility, and now in grass."

Up to and including 1917 these soil tests were under the supervision of Dr. William P. Brooks, formerly agriculturist and later director and agriculturist of the Experiment Station. Progress reports under the authorship of Dr. Brooks were made in Bulletins Nos. 9, 14, 18 and 58 of the Hatch Experiment Station, and likewise in the annual reports of that Station and its successor, the Massachusetts Agricultural Experiment Station. Records from these tests, with analysis and discussion, were also published in "Das Nährstoffbedürfnis Verschiedener in Fruchtfolge auf demselben Felde Angebauter Pflanzen nach Versuchen in Massachusetts, Nordamerika," presented by Dr. Brooks at the University of Halle, Germany, as a doctorate dissertation.

The greatest service of these field tests to date has probably been the establishment of the fact that individual crops vary widely in their plant food requirements, and that fertility practice may be affected more by the kind of crop than by the type of soil on which it is grown. Dr. Brooks presented this idea in his summarization of these experiments published in Bulletin No. 58 above cited, and was one of the first, if not the first, of the fertility workers of the country to observe this fact. Results secured during the score of years which has elapsed since the observation was first made have confirmed the conclusion in abundant measure.

The South Soil Test.

This test is on a soil classified in the soil survey of the Connecticut Valley as a Merrimac coarse sandy loam. The field is practically level, and had been in grass without manure for five years previous to the laying out of the test. Earlier still, for an unknown number of years, it had been in pasture.

Cropping System.

The original plan was apparently that of a five-year rotation, consisting of two years of corn, then a grain crop, followed by two years of grass and clover. This plan, however, was not followed consistently, although, in the thirty years of which we have full record, thirteen corn crops were grown. A complete list of crops as grown year by year is contained in Table I of the Appendix.

Fertilizer Treatment.

The fertilizer treatment is shown in the following schedule: —

Plot.	Fertilizer.	Pounds per Acre.
1	Nitrate of soda	160
2	Dissolved boneblack	320
3	Nothing.	
4	Muriate of potash	160
5	Lime	800
6	Nothing.	
7	Manure	30,000
8	Nitrate of soda Dissolved boneblack	160 320
9	Nothing.	
10	Nitrate of soda Muriate of potash	160 160
11	Dissolved boneblack Muriate of potash	320 160
12	Nothing.	
13	Plaster	800
14	Nitrate of soda Dissolved boneblack Muriate of potash	160 320 160

The plots were 18 by 121 feet in size, or exactly one-twentieth of an acre. A strip 3 feet wide between plots was cultivated as though a part of the adjacent plots, but yields on these strips were never recorded.

Lime History.

Lime was applied in the following amounts: —

Year.		Pounds per Acre.
1899.	Slaked lime	2,000
1904.	Slaked lime, about	3,000
1907.	Agricultural lime, about	1,000
1909.	Agricultural lime	2,000
1916.	Ground limestone	4,000

Precipitation and Frost Records.

Tables II and III in the Appendix show the observations on temperature, frost and precipitation as taken by the Department of Meteorology of the Experiment Station for the years from 1889 to 1921, inclusive.

During this thirty-three-year period there have occurred certain fairly definite weather cycles. For a period of eight years, 1897 to 1904, inclusive, the annual rainfall was consecutively above the mean for the period. From 1907 to 1914, inclusive, with the exception of a single year, the annual precipitation was below the mean of the period, and averaged 10 inches annually below that of the preceding period. From 1907 to 1913 the rainfall of the growing season, April to August, inclusive, averaged 14.7 inches; while for the succeeding seven years the average for the same period was 20.3 inches. There were also in the whole period wide extremes in total precipitation, the least being 10.82 inches for the growing period in 1894, and the highest 32.25 inches in 1892. The growing season, or the time between the last killing frost of the spring and the first killing frost of autumn, varied from 99 days in 1894 to 164 days in 1920. With such wide variations in weather conditions, especially as regards the dominant influence of precipitation, temperature and length of season, it is not to be expected that results from fertilizer use would in all cases be as expected, or show records always consistent one with the other.

Yields.

A complete statement of yields is given in Table I of the Appendix. Corn was grown more often than any other single crop, there having been a total of thirteen corn crops. For two years preceding the eleventh crop, however, the land was practically fallow; while the twelfth and thirteenth crops followed partial or total crop failures. The best picture of results, therefore, may be obtained by considering the corn crop as the common denominator of all the crops, and dividing the corn yields into three periods, including the first five crops in the first, the second five in the second, and the last three somewhat abnormal crops in the third, as shown in Table 1: —

TABLE 1. — *The Corn Crops.*

Grain (Average Yields per Acre, Bushels).

Plot.	Treatment.	First Period.	Second Period.	Third Period.
1	Nitrate of soda	26.73	6.05	26.55
2	Dissolved boneblack	23.96	4.52	13.03
3	Nothing	20.74	4.31	10.97
4	Muriate of potash	44.61	31.83	44.79
5	Lime	23.71	2.81	9.26
6	Nothing	20.79	5.27	11.08
7	Manure	63.11	57.20	56.13
8	Nitrate of soda Dissolved boneblack	32.33	9.84	–[1]
9	Nothing	25.37	5.53	–[1]
10	Nitrate of soda Muriate of potash	42.07	35.38	43.85
11	Dissolved boneblack Muriate of potash	54.90	39.33	44.53
12	Nothing	23.10	7.50	20.43
13	Plaster	27.09	9.14	14.54
14	Nitrate of soda Dissolved boneblack Muriate of potash	62.46	41.89	38.52

[1] These plots were discontinued in 1911.

These results are presented in graphic form in Fig. 1, arranged to show the total yields of grain and stover, and likewise the comparative yields in the two five-year periods. It will be noted that the yield of grain decreased very materially and significantly in the second five-year period. In all of those plots to which potash treatment was applied, the yield of stover did not decrease in like measure. On the other hand, where potash was not applied, the decrease in the yield of stover was somewhat similar in its significance to the decrease in grain. In all cases, the number of pounds of stover produced per bushel of grain was larger in the second period than in the first, and very materially so in the no-potash treatments.

The First Ten Corn Crops.

The Check Plots. — The significance of the results and their interpretations may best be judged on the basis of the yields on the check plots. There were four such plots, numbered respectively, 3, 6, 9 and 12. The following table shows the yields of corn divided into two five-year periods. Under the system of farming followed, the yielding power of the untreated soil was very low. The acre yields in the second period were practically zero. The check plots were, however, fairly uniform in production.

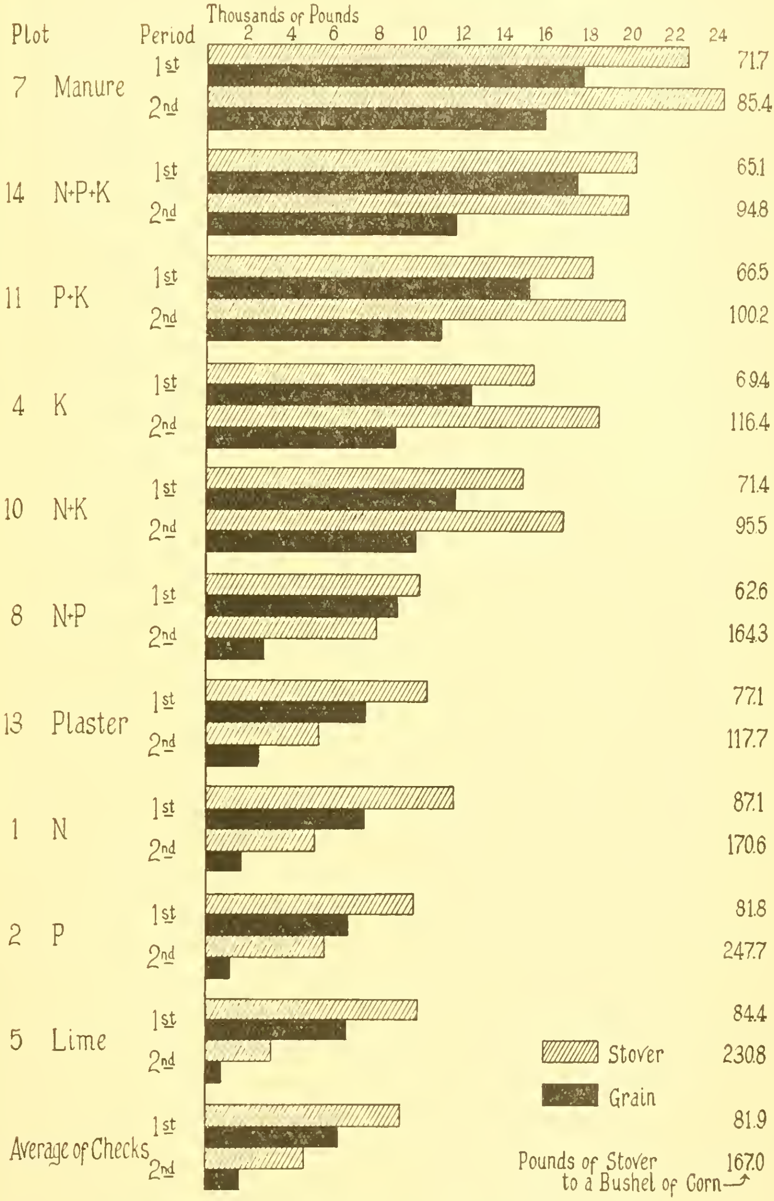


FIG. 51. — South Soil Test. Total yields per acre. Ten corn crops.

TABLE 2. — *The Check Plots.*

Plot.	Corn (Bushels per Acre). First Period.	Second Period.	Decrease.
3	20.74	4.31	16.43
6	20.79	5.27	15.52
9	25.37	5.53	19.84
12	23.10	7.50	15.60

The Effect of Potash. — The most marked and most striking result of the test, especially as indicated by the corn crop, was the great response to potash. The following table shows the average yields of corn for the two periods under discussion for those treatments which include this plant food: —

TABLE 3. — *The Treatments containing Potash.*

Plot.	Treatment.	Corn (Bushels per Acre). First Period.	Second Period.	Decrease.
4	Muriate of potash	44.61	31.83	12.78
7	Manure	63.11	57.20	5.91
10	Nitrate of soda Muriate of potash	42.07	35.38	6.69
11	Dissolved boneblack Muriate of potash	54.90	39.33	15.57
14	Nitrate of soda Dissolved boneblack Muriate of potash	62.46	41.89	20.57

Potash alone was effective, although the difference between the first period and the second period is very large. This treatment outyielded the potash and nitrogen treatment in the first period, but results were reversed in the second.

The use of a mineral plant-food ration consisting of phosphoric acid and potash gave marked results. Here again, however, the decrease in yield between the two periods was fully as great as, in fact somewhat larger than, the decrease on either the potash or potash and nitrogen plots. On the complete fertilizer, however, the decrease was even greater; for whereas this treatment was definitely superior in yield during the first period, it was very little better than the phosphoric acid and potash treatment in the second.

There are two explanations for this apparent decrease in yielding power in the two periods under discussion. The weather conditions may not have been the same for the two series of corn years; and the destructive system of farming followed may have seriously affected the ability of the soil to produce crops on fertilizers alone, as compared to its ability to produce crops on barnyard manure.

With reference to the first possibility, Table 6, page 136, presents data for moisture and temperature during all of the years in question. An attempt is made to epitomize these records in a single sentence descriptive of the growing conditions for the years in question. Bringing these together, the following picture is obtained of the comparative growing conditions in the two periods: —

First Period.		*Second Period.*	
1889.	Warm and moist in the early season.	1902.	Cool with abundant moisture.
1890.	Normal.	1903.	Drought in May; very cold and wet in June; very cold in August.
1894.	Warm and generally dry following a dry winter.	1904.	Wet spring; cool.
1898.	Good growing season.	1907.	Cold and dry following a dry winter.
1899.	Slight moisture deficiency.	1910.	Drought.

It is evident that the weather conditions in the last period were less favorable than in the first period.

In interpreting the significance of the above facts, thought must be given to the farming system followed. At the very beginning the stage was apparently set, although unconsciously, for a crop increase from the use of fertilizer potash. Grass, a heavy potash feeder, had been occupying the land for a number of years, but without return to the soil of either manure or fertilizer. As the years passed, this initial condition was accentuated through the removal from the soil of successive crops of corn and of grass and clover. Had these crops been fed on the farm, as in practical agriculture they must have been, there would have been potash return to the soil by natural means and less need for the use of commercial potash.

The Destructive Treatments. — A number of treatments were definitely destructive, *i.e.*, yields decreased definitely and significantly from one period to another, and reached a point at which profitable farming would have been absolutely impossible. Nitrate of soda alone, acid phosphate alone, lime alone, nitrate of soda and acid phosphate, and land plaster come in this list. The average yields for the first and second periods for plots treated with these materials were as follows: —

TABLE 4. — *The Destructive Treatments.*

Plot.	Treatment.	Corn (Bushels per Acre). First Period.	Second Period.	Decrease.
1	Nitrate of soda	26.73	6.05	20.68
2	Dissolved boneblack	23.96	4.52	19.44
5	Lime	23.71	2.81	20.90
8	Nitrate of soda Dissolved boneblack	32.33	9.84	22.49
13	Plaster	27.09	9.14	17.95

Since the farming system followed was one which logically and on many soils inevitably results in need of complete fertilizer applied in large quantities, it is not astonishing that the one-sided treatments should give such poor results.

It will be noted that the above-mentioned destructive treatments are those which contain no potash, which fact is of importance in connection with the lime history of the field. Commencing in 1899, lime was applied at frequent intervals, and in generous quantity. It has sometimes been claimed that such use of lime makes soil potash available. Did it have such an effect, it would be expected that the yields on the nitrate of soda, the dissolved boneblack (acid phosphate) and the nitrate and boneblack plots would approximate those secured on equivalent treatments with potash added. This expectation has not been realized. There is no indication in the data at hand that lime has had any measurable or significant effect in increasing the availability of soil potash.

Manure versus Fertilizer. — Table 5 shows the comparative corn yields year by year, with averages for the two periods in question, of Plot 7, receiving manure, and Plot 14, receiving complete fertilizer.

TABLE 5. — *Comparison of Manure and Complete Fertilizer.*

First Period. Year.	Corn (bushels per acre). Plot 7, Manure.	Plot 14, Complete Fertilizer.	Second Period. Year.	Corn (bushels per acre). Plot 7, Manure.	Plot 14, Complete Fertilizer.
1889	57.50	61.50	1902	68.70	56.20
1890	59.75	71.00	1903	37.39	25.56
1894	54.70	51.00	1904	50.00	47.78
1898	67.70	55.90	1907	72.50	38.31
1899	75.90	72.90	1910	57.43	41.57
Average	63.11	62.46	Average	57.20	41.89

For the first five crops the two treatments gave practically the same results. For the last five crops, yields were maintained fairly well by the manure treatment, and not at all well on the fertilizer treatment. This difference in plot behavior may be explained, in part, either by the fact that manure contained organic matter while the fertilizer used did not, or by the difference in plant food. The amounts of plant food applied per acre in the two contrasted treatments are as follows: —

	Pounds per Acre (Average per Year).	
	Applied in Manure.	Applied in Fertilizer.
Nitrogen	108	24
Phosphoric acid	118	51
Potash	169	80

The amount of manure used is larger than could have been produced had all crops grown been fed to animals and all of the manure produced carefully saved and returned to the land. For this reason the fact brought out in the foregoing table has no great significance in its bearing on actual practice.

Response of Corn to Fertilizer Nitrogen. — There was wide variation in the degree of response of the crop to the use of fertilizer nitrogen. In two cases there was apparently a significant decrease in crop produced by such use, — a result which, while unusual, is by no means impossible. Owing to its favorable effect on nitrification, corn seldom shows marked response to the use of this plant food except under those conditions where the soil supply of organic nitrogen is very limited. Less response would therefore be expected on the corn crops following legumes or grown on sod than on the corn crops following non-legumes or grown on stubble, while the greatest increase would be expected from those corn crops which are three years from a legume.

The following tabulation was made to see if this expectancy be supported by facts. Owing to the comparatively small variation in checks, the yields on the phosphoric acid and potash plot are compared directly with those on the complete fertilizer plots. The yields on the manure plots are included, as significant of results secured where there was a sufficiency of plant food and organic matter in the soil. Since moisture and temperature conditions influence nitrification, the departure from normal of both precipitation and mean hourly temperature is tabulated alongside the yield records.

TABLE 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation and Weather Conditions.*

CORN, YIELDS PER ACRE, SOUTH SOIL TEST.

I. *Following Legume or "Old Sod."*

[The first row of figures under the date line is bushels of corn per acre; the second row, pounds of stover per acre.]

Precipitation (Inches). Above Normal.		Precipitation (Inches). Below Normal.	Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit). Above Normal.		Mean Hourly Temperature (Degrees Fahrenheit). Below Normal.
			1889.					
	April	—0.84	57.50	58.00	61.50	+3.2	April	
+1.03	May		4,200	3,960	4,180	+4.0	May	
+1.63	June		Warm and moist in early season.			+2.0	June	
+6.11	July						July	—1.1
	August	—1.53					August	—2.5
			1894.					
	April	—1.42	54.7	49.5	51.0	+1.8	April	
+0.32	May		3,760	3,820	3,780	+1.3	May	
	June	—0.25	Warm and generally dry following a dry winter.			+3.7	June	
	July	—2.86				+2.9	July	
	August	—3.94				+1.3	August	
			1902.					
+0.05	April		68.7	55.9	56.2	+1.2	April	
	May	—1.36	6,220	4,640	4,540		May	—0.4
+1.16	June		Cool and abundant moisture.				June	—2.2
+0.25	July						July	—2.8
+0.40	August						August	—1.9
			1907.					
	April	—1.28	72.50	30.13	38.31		April	—4.6
+0.34	May		6,900	6,500	5,500		May	—5.6
	June	—1.02	Cold and dry following a dry winter.				June	—1.8
	July	—0.54					July	—0.6
	August	—2.81					August	—1.9
			1913.					
+0.04	April		66.8	49.7	44.4	+1.5	April	
+1.26	May		5,140	4,040	3,840		May	—1.8
	June	—2.48	Dry from June on.			+0.7	June	
	July	—2.82				+0.8	July	
	August	—1.99				+1.5	August	
			1915.					
+0.73	April		60.79	37.58	35.15	+3.8	April	
	May	—2.48	3,520	3,250	3,400		May	—3.3
	June	—0.38	Cool, with flood conditions in late season.				June	—1.5
+4.72	July						July	—1.7
+4.03	August						August	—2.0
			1917.					
	April	—1.43	40.8	46.3	36.0		April	—3.2
+0.45	May		5,200	3,300	5,400		May	—8.1
+1.89	June		Very cool in early season.				June	—0.4
	July	—1.05				+1.1	July	
+2.81	August					+2.9	August	

TABLE 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation, and Weather Conditions* — Continued.

CORN, YIELDS PER ACRE, SOUTH SOIL TEST — *Concluded.*

II. *Second Year after Legume or Sod.*

Precipitation (Inches).			Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit).		
Above Normal.		Below Normal.				Above Normal.		Below Normal.
			1890.					
	April	—1.53	59.75	65.90	71.00	+0.4	April	
+1.71	May		5,520	4,880	5,320		May	—0.3
	June	—1.85	"Normal."				June	—0.4
+1.22	July						July	—0.8
+0.63	August						August	—0.8
			1898.					
+0.47	April		67.7	41.2	55.9		April	—3.1
+1.93	May		3,800	2,440	2,600		May	—1.8
+0.31	June		Good growing conditions.			+0.3	June	
+0.32	July					+0.3	July	
+2.60	August					+1.7	August	
			1903.					
	April	—0.96	37.39	20.39	25.56	+0.8	April	
	May	—3.20	3,600	2,320	3,040	+1.8	May	
+4.41	June		*Drought in May;* very cold and wet in June; very cold in August.				June	—6.1
+0.23	July						July	—1.7
+0.67	August						August	—6.0
			1910.					
	April	—0.19	57.43	37.14	41.57	+4.5	April	
	May	—1.01	3,700	2,300	3,080		May	—1.3
	June	—0.73	Drought.				June	—1.9
	July	—2.51				+1.5	July	
	August	—0.22					August	—0.9

III. *Third Year after Legume or Sod.*

			1899.					
	April	—1.47	75.9	59.9	72.9		April	0
	May	—2.40	5,350	3,160	4,450		May	—1.7
+0.75	June		Slight moisture deficiency.			+1.7	June	
+0.48	July						July	—0.5
	August	—2.25					August	0
			1904.					
+2.47	April		50.00	53.11	47.78		April	—3.6
+0.87	May		4,000	3,940	3,700	+2.7	May	
+1.97	June		Wet spring; cool.				June	—0.7
	July	—1.79					July	—0.8
	August	—0.16					August	—1.6

Table 6. — *Relationship between Increase from Fertilizer Nitrogen, Place in Rotation, and Weather Conditions* — Concluded.

Corn, Yields per Acre, North Soil Test.

I. *Following Legume or Sod.*

Precipitation (Inches).			Manure.	Phosphoric Acid and Potash.	Nitrogen, Phosphoric Acid and Potash.	Mean Hourly Temperature (Degrees Fahrenheit).		
Above Normal.		Below Normal.				Above Normal.		Below Normal.
			1890.					
			Whole Plot.					
	April	—1.53		74.0	74.9	+0.4	April	
+1.71	May			5,740	5,820		May	—0.3
	June	—1.85	"Normal."				June	—0.4
+1.22	July						July	—0.8
+0.63	August						August	—0.8
			1905.					
			Limed.					
	April	—0.70		34.24	43.06		April	—0.5
	May	—2.40		3,400	4,840		May	—0.5
	June	—0.52	Cool and very dry.				June	—1.3
	July	—1.78				+0.5	July	
+2.22	August						August	—2.2
			Unlimed.					
				11.29	36.24			
				4,520	5,840			
			1916.					
			Limed.					
+0.43	April			48.1	41.2		April	—2.2
	May	—0.47		4,000	4,200		May	—1.5
+1.96	June						June	—4.6
+2.44	July					+1.0	July	
	August	—1.76				+1.5	August	
			Unlimed.					
				30.3	38.3			
				2,500	4,200			

In the year following a legume there has been no consistent response of the crop to the use of fertilizer nitrogen, and this almost without regard to the condition of the weather. The second year after a legume, however, there has been such response, — in one case in a marked degree. In the two cases where corn was planted three years after the legume, one showed an apparent increase rather significant in size, the other an apparent decrease.

For comparison, the results of the three corn crops grown on the North Soil Test are presented. All of these were grown after sod or legume. On the limed section or on the undivided plot, nitrogen brought a crop increase in one case out of three. On the unlimed section, in the two years of record, there was a definite increase. This result may trace back to the poor growth of the clover on the unlimed land.

The Last Three Corn Crops.

Cultural methods from 1909 on departed widely from the normal. In 1908 a catch crop of crimson clover was turned under as a green manure. In 1909 a partial crop of buckwheat was turned under. In 1911 there was a cultivated fallow, and in 1912 something which in its effect was practically a fallow. The 1913 corn crop therefore had the benefit of two years of soil idleness. In 1914 a crop of soy beans failed to mature, and hence presumably left more of value in the stubble than would have been the case had the crop ripened its seed. In 1916 sweet clover was sown, but the crop appeared to be mostly weeds. This was cut and removed from the soil but not weighed. The corn crops of 1913, 1915 and 1917 therefore are not comparable with the earlier crops, although they may indicate the fertility tendencies as brought about by this abnormal treatment.

The Hay Crops.

There were six crops of grass and clover. One of the most marked results in the whole history of the experiment was the character of the vegetation produced by differential fertilizer treatment on uniform seeding. Clovers failed to grow where potash was not applied. The effect of this is shown primarily in the rowen crop, which consisted largely of clover. The number of hay crops was, however, too small and the crop too responsive to varying weather conditions to admit of any very satisfactory interpretation of the data. The graphic presentation (Fig. 2) represents the total yields for the six crops.

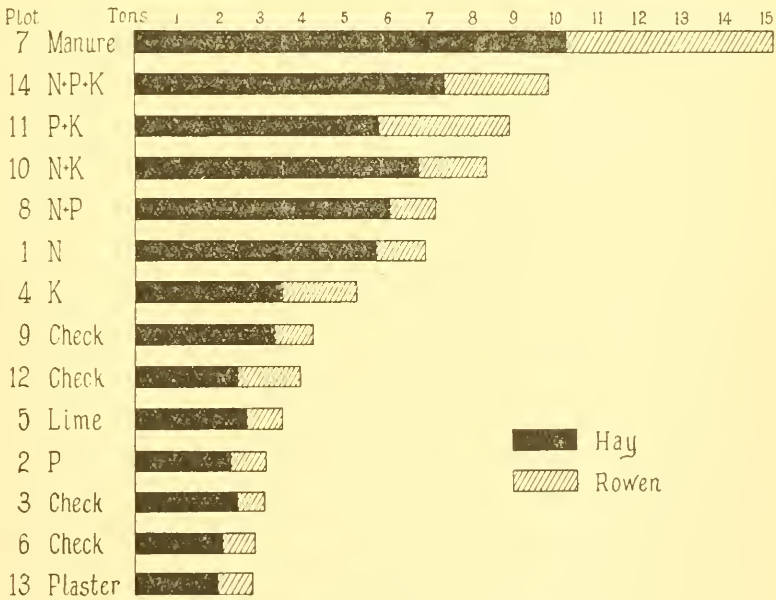


FIG. 2. — South Soil Test. Total yields per acre. Six hay crops.

Financial Interpretation.

No satisfactory financial interpretation of the results of the experiment is possible. Fertilizers were applied according to a set schedule, without reference to the value of the crop or to its ability to make payment through increased acre value for the plant food applied. Neither was there any attempt to estimate the necessity of one plant food or another as indicated by the previous history of the plots, and response of the crops grown to varying fertility treatments.

The North Soil Test.

History.

This field was started in 1890. Previously it had been pasture, without definite manure application, for a number of years. The plots are located about 150 yards from the South Soil Test, and are on soil of the same formation, although with a more definite slope toward the west. Fig. 3 shows the shape and arrangement of plots as compared with the South Soil Test.

Fertilizer Treatment.

The fertilizer treatment was the same in principle as that on the South Soil Test, except that the plots were differently laid out and hence bore different numbers. The schedule follows: —

Plot.	Treatment.	Pounds per Acre.
1	No fertilizer.	
2	Nitrate of soda	160
3	Dissolved boneblack	320
4	No fertilizer.	
5	Muriate of potash	160
6	Nitrate of soda Dissolved boneblack	160 320
7	Nitrate of soda Muriate of potash	160 160
8	No fertilizer.	
9	Dissolved boneblack Muriate of potash	320 160
10	Nitrate of soda Dissolved boneblack Muriate of potash	160 320 160
11	Plaster	800[1]
12	No fertilizer.	

[1] 1892–95, 160 pounds per acre; 1896, increased to 400 pounds per acre; 1902, increased to 800 pounds per acre.

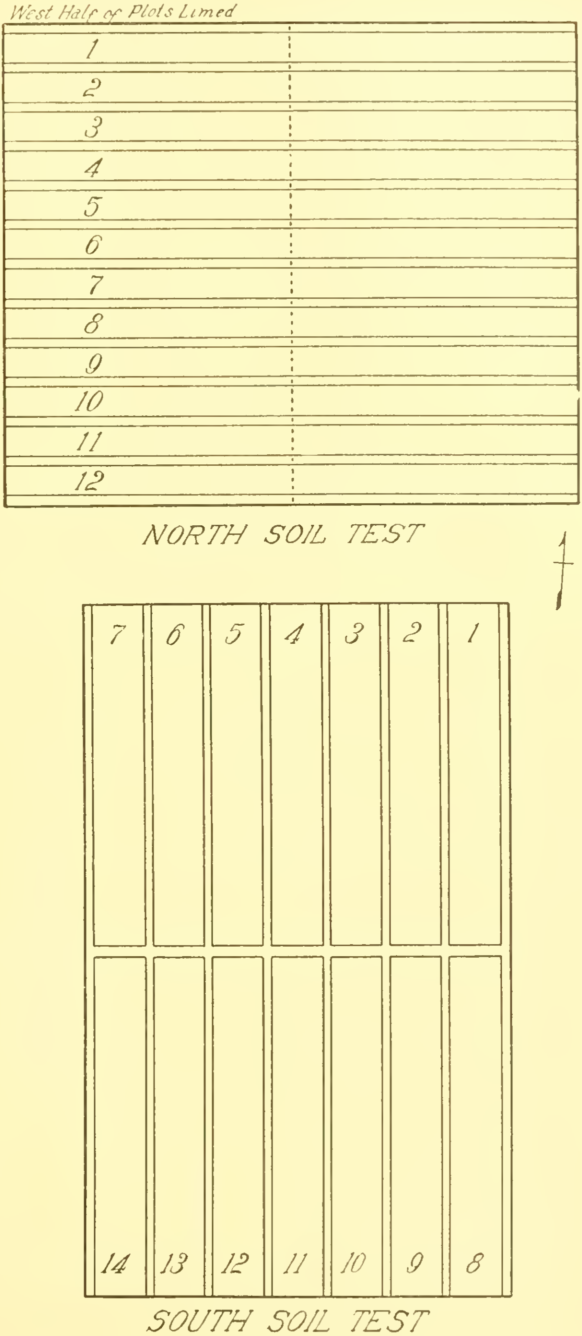


FIG. 3. — Plan of the plots.

In 1897 and 1902 for potatoes, in 1898, 1899, 1900 and 1901 for onions, and in 1903 and 1904 for grass and clover, the fertilizer applications were doubled. In 1899 lime was applied to the west half of the field, and was repeated in 1904, 1907 and 1916, a total of 4½ tons per acre of lime in one form or another being applied over a period of eighteen years.

Table IV of the Appendix gives the record of yields over the period of the experiment.

Variation in Checks.

The check plots were very variable. The yields of grass and clover on the limed and unlimed halves of the field illustrate this fact.

TABLE 7. — *Grass and Clover Yields on Check Plots (Yields per Acre, Pounds).*

Year.	Unlimed.				Limed.			
	Plot 1.	Plot 4.	Plot 8.	Plot 12.	Plot 1.	Plot 4.	Plot 8.	Plot 12.
1903	360	**550**	450	420	**1,150**	1,010	570	1,140
1904	**1,200**	590	600	650	880	690	1,440	**1,520**
1908	**1,340**	780	480	440	2,160	1,560	1,640	**2,220**
1909	**1,280**	1,180	1,150	720	**1,570**	1,520	1,560	1,520
1914	**1,600**	1,240	820	600	1,840	2,030	2,920	**3,060**
1915	920	**1,020**	520	480	1,480	2,220	2,320	**2,940**

The highest yielding plots in each year are bold-faced type.

Plot 1 on the limed and unlimed portions of the field is seemingly superior, at least in its ability to grow grass and clover, to Plots 4 and 8. Plot 12, unlimed, is the poorest of the checks, while on the limed portion of the field it is superior to Plot 1. Owing to this variation in different parts of the field, the data presented in Table IV of the Appendix do not permit of clear-cut numerical discussion. They serve to indicate tendencies rather than to furnish statistical proof. It is probable, also, that the natural variation in the checks has been exaggerated somewhat by the fact that there has been cross washing on this field, the soil working in a more or less diagonal direction from the unlimed portion of Plot 12 to the limed half of Plot 1.

Effect of Lime and of Fertilizer Applications.

Even though the uniformity of conditions is not as great as could be desired, the results from the use of many of the plant food and lime combinations are so striking as to be beyond the range of probable experimental error. Table 8 has accordingly been prepared, showing the comparisons for a number of the more important crops grown. From this table the following facts are developed: —

1. The effect of lime is very marked, but crop increase from its use is less when it is added to phosphoric acid alone, or to phosphoric acid and nitrogen, than when added to any other treatment. In general, the phosphoric acid and nitrogen treatment on the unlimed portion of the field leads all except the complete fertilizer. On the limed portion, however, complete fertilizer, phosphoric acid and potash, nitrogen and potash, and, occasionally, potash alone are superior.

2. The gain from applying lime in addition to a ration of potash alone is very much greater than from applying it in addition to phosphoric acid.

3. Potash has not given as marked results as on the South Soil Test.

4. The use of potash, phosphoric acid and lime has maintained yields at a comparatively high level, despite the infrequency with which clovers have been grown.

5. Nitrogen, used in addition to phosphoric acid and potash, has given fairly large increases in crop.

Effect of Lime on the Availability of Soil Potash.

On the limed half of this field there are three comparisons — namely, nitrogen with and without potash, phosphoric acid with and without potash, nitrogen and phosphoric acid with and without potash — where the effect of lime in increasing the availability of soil potash should be apparent. Table 9 shows the crop yields secured and presents the estimated gain from the use of potash in each case.

TABLE 8. — *The Interrelation of Lime and Fertilizer (Yields per Acre).*

Crop.	Average of Checks (Plots 1, 4, 8, 12).			Nitrogen (Plot 2).			Phosphoric Acid (Plot 3).			Potash (Plot 5).		
	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.
Grass and clover:												
1903	968	445	-	3,140	1,520	-	1,560	950	-	950	660	-
1904	1,133	760	-	1,690	2,020	-	800	1,060	-	2,700	670	-
1908	1,895	760	-	3,880	3,280	-	1,600	940	-	2,380	860	-
1909	1,543	1,083	-	1,780	1,980	-	1,420	1,260	-	3,640	1,050	-
1914	2,463	1,065	-	2,870	2,020	-	1,680	1,490	-	5,540	1,280	-
1915	2,240	735	-	1,580	1,440	-	1,380	1,180	-	6,750	1,580	-
Average	1,707	808	+899	2,490	2,013	+447	1,407	1,147	+260	3,660	1,017	+2,643
Beans (green weight), 1918	1,005	1,680	—675	960	1,240	—280	800	960	—160	3,840	2,320	+1,520
Cabbage, 1917	18,410	1,365	+17,045	23,240	3,080	+20,160	9,220	9,800	—580	22,680	1,580	+21,100
Corn, grain (bushels):												
1905	13.7	8.7	-	9.1	13.9	-	5.9	7.8	-	18.4	5.7	-
1916	27.1	20.2	-	19.7	34.5	-	21.7	35.1	-	36.9	25.9	-
Average	20.4	14.5	+5.9	14.4	24.2	—9.8	13.8	21.4	—7.6	27.8	15.8	+12.0
Corn, stover:												
1905	2,810	2,800	-	3,960	480	-	2,640	3,400	-	4,400	4,040	-
1916	1,800	1,700	-	1,600	2,200	-	1,600	3,000	-	2,600	3,000	-
Average	2,305	2,250	+55	2,780	1,340	+1,440	2,120	3,200	—1,080	3,500	3,520	—20
Soy beans (bushels):												
1906	7.6	10.5	-	3.5	4.5	-	4.0	5.5	-	12.4	8.3	-
1910	17.7	12.1	-	19.3	14.8	-	13.8	11.4	-	24.8	9.0	-
1911	6.3	10.6	-	2.1	4.7	-	.9	4.7	-	20.3	14.5	-
Average	10.5	11.1	—.6	8.3	8.0	+.3	6.2	7.2	—1.0	19.2	10.6	+8.6

Soy beans, straw:												
1906	503	660	-	490	440	-	400	380	-	720	520	-
1910	3,235	1,625	-	3,480	3,140	-	2,800	2,680	-	1,560	1,680	-
1911	2,033	1,848	-	1,480	1,450	-	950	1,530	-	2,820	2,160	-
Average	1,924	1,378	+546	1,817	1,677	+140	1,383	1,530	—147	1,700	1,453	+247
Onions (bushels):												
1899	19.5[1]	3.7[1]	-	91.4	18.7	-	12.3	6.5	-	161.7[1]	3.1	-
1900	95.9	35.2	-	155.0	50.0	-	37.7	17.3	-	383.5	37.7	-
Average	57.7	19.5	+38.2	123.2	34.4	+88.8	25.0	11.9	+13.1	272.6	20.4	+252.2
Potatoes (bushels), 1902	48.7	54.1	—5.4	47.6	50.7	—3.1	48.0	59.3	—11.3	81.7	73.3	+8.4
Rye, grain (bushels):												
1913	33.9	24.1	-	36.4	30.7	-	28.9	29.6	-	35.3	28.9	-
1921	13.1	8.6	-	11.8	10.0	-	12.1	11.8	-	15.5	10.4	-
Average	23.5	16.4	+7.1	24.1	20.4	+3.7	20.5	20.7	—.2	25.4	19.7	+5.7
Rye, straw:												
1913	5,075	3,725	-	6,220	4,060	-	5,180	3,860	-	5,220	4,380	-
1921	1,515	1,010	-	1,340	1,240	-	1,340	1,490	-	1,820	1,320	-
Average	3,295	2,368	+927	3,780	2,650	+1,130	3,260	2,675	+585	3,520	2,850	+670

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

TABLE 8. — *The Interrelation of Lime and Fertilizer (Yields per Acre)* — Concluded.

Crop.	Phosphoric Acid and Nitrogen (Plot 6).			Potash and Nitrogen (Plot 7).			Phosphoric Acid and Potash (Plot 9).			Complete Fertilizer (Plot 10).		
	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.	Limed.	Unlimed.	Apparent Gain from Liming.
Grass and clover:												
1903	3,180	1,830	-	2,190	1,820	-	920	620	-	2,830	2,330	-
1904	3,130	2,330	-	2,380	1,970	-	6,160	940	-	7,240	2,820	-
1908	4,600	3,720	-	3,800	3,240	-	3,240	800	-	4,730	4,240	-
1909	2,760	2,010	-	2,980	1,240	-	3,840	920	-	2,520	1,790	-
1914	3,840	2,540	-	4,080	2,000	-	4,420	1,030	-	6,110	2,600	-
1915	4,190	1,280	-	5,560	960	-	5,220	580	-	5,800	900	-
Average	3,617	2,285	+1,332	3,498	1,872	+1,626	3,967	815	+3,152	4,872	2,447	+2,425
Beans (green weight), 1918	2,200	1,980	+220	4,360	2,380	+1,980	3,040	1,680	+1,360	3,740	2,500	+1,240
Cabbage, 1917	27,440	23,160	+4,280	28,000	1,000	+27,000	32,720	13,880	+18,840	45,400	33,360	+12,040
Corn, grain (bushels):												
1905	29.2	20.2	-	29.5	12.5	-	34.2	11.3	-	43.1	36.2	-
1916	41.3	43.3	-	45.7	25.1	-	48.1	30.3	-	51.2	38.3	-
Average	35.3	31.8	+3.5	37.6	18.8	+18.8	41.2	20.8	+20.4	47.2	37.8	+9.4
Grain, stover:												
1905	3,680	3,600	-	3,720	2,960	-	3,400	4,520	-	4,840	5,840	-
1916	2,800	3,600	-	3,800	2,900	-	4,000	2,500	-	4,200	4,200	-
Average	3,240	3,600	—360	3,760	2,930	+830	3,700	3,510	+190	4,520	5,020	—500
Soy beans (bushels):												
1906	9.5	6.9	-	14.1	9.7	-	10.3	6.9	-	14.1	7.9	-
1910	18.6	14.5	-	19.0	8.3	-	19.7	4.8	-	16.6	8.3	-
1911	6.9	10.9	-	20.7	14.5	-	15.9	14.3	-	20.2	17.1	-
Average	11.7	10.8	+.9	17.9	10.8	+7.1	15.3	8.7	+6.6	17.0	11.1	+5.9

Soy beans, straw:												
1906	760	520	-	780	740	-	600	420	-	920	400	-
1910	4,120	2,160	-	1,820	1,520	-	1,460	1,040	-	3,240	2,200	-
1911	2,600	2,290	-	3,000	2,360	-	2,880	3,370	-	3,830	3,610	-
Average	2,493	1,657	+836	1,867	1,540	+327	1,647	1,610	+37	2,663	2,070	+593
Onions (bushels):												
1899	145.4	143.1	-	200.0[1]	3.1	-	183.8	40.4[1]	-	224.6	46.2[1]	-
1900	202.3	225.8	-	310.8	9.2	-	380.0	159.6	-	488.5	136.9	-
Average	173.9	184.5	—10.6	255.4	6.2	+249.2	281.9	100.0	+181.9	356.5	91.5	+265.0
Potatoes (bushels), 1902	100.3	98.0	+2.3	75.6	77.3	—1.7	113.7	91.7	+22.0	132.6	127.3	+5.3
Rye, grain (bushels):												
1913	35.3	27.9	-	35.3	22.9	-	31.1	17.1	-	35.7	21.8	-
1921	15.7	16.4	-	13.9	10.0	-	6.1	9.6	-	7.1	7.5	-
Average	25.5	22.2	+3.3	24.6	16.5	+8.1	18.6	13.4	+5.2	21.4	14.7	+6.7
Rye, straw:												
1913	5,020	4,240	-	5,620	4,720	-	5,260	3,640	-	5,600	3,780	-
1921	1,760	960	-	1,440	1,240	-	2,360	1,300	-	1,280	800	-
Average	3,390	2,600	+790	3,530	2,980	+550	3,810	2,470	+1,340	3,440	2,290	+1,150

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

Table 9. — *Yields per Acre, Limed Portion of Field.*

Treatment.	Corn (2 Crops) (Bushels).		Grass and Clover (6 Crops) (Pounds).		Soy Beans (3 Crops) (Bushels).	
	Yield.	Gain from Use of Potash.[1]	Yield.	Gain from Use of Potash.[1]	Yield.	Gain from Use of Potash.[1]
Nitrogen alone	14.4		2,490		8.3	
Nitrogen and potash	37.6	23.2	3,498	1,008	17.9	9.6
Phosphoric acid alone	21.7		1,407		6.2	
Phosphoric acid and potash	41.2	19.5	3,967	2,560	15.3	9.1
Nitrogen and phosphoric acid	35.3		3,617		11.7	
Complete fertilizer	47.2	11.9	4,872	1,255	17.0	5.3

[1] By difference.

The large and consistent differences secured through the use of potash indicate that whatever effect the lime may have had on the availability of soil potash was relatively insignificant. This checks the results secured on the South Soil Test, as already discussed.

Miscellaneous Effects of Fertilizers on Crops.

Even though the fertilizer applications were in some cases doubled, as indicated on page 142, either the soil conditions were unfavorable or the amount of plant food applied was too small to give satisfactory crops of onions or potatoes. The yield of 488 bushels of onions on the limed complete fertilizer plot in 1900 is indeed well above the average, but still is not a large yield. In 1898 and likewise in 1901, the crop was a failure. The yield records do, however, indicate two things very strongly: first, the great importance to the onion crop of maintaining a suitable reaction of the soil; and second, the need by the crop of large quantities of all three of the essential plant foods. The potato crops of 1897 and 1902 were virtual failures.

The cabbage crop of 1917 was remarkably satisfactory and furnishes several illustrations of the fact that crops of the same size may be secured through radically different plant food treatments. As an illustration, the crop on the limed half of Plot 9, which in 1917 had been receiving phosphoric acid and potash annually for twenty-seven years, was the same as the crop on complete fertilizer without lime. Neither one of these, however, approached the crop produced with complete fertilizer and lime. Again, the crop on the limed portion of Plot 6, which had received no potash for twenty-seven years, was almost identical with that on the limed portion of Plot 7, which had received no phosphoric acid for the

PLATE I.

CROP RESPONSE TO NITROGEN AND LIME.

CABBAGES, CROP OF 1917.

Potash and phosphoric acid with lime. Yield per acre: good, 25,000 pounds; poor, 7,720 pounds.

Potash, phosphoric acid and nitrogen without lime. Yield per acre: good, 26,040 pounds; poor, 7,320 pounds.

A. Lime versus *Nitrogen.*

A very fair crop was produced with potash and phosphoric acid plus lime, or with complete fertilizer without lime.

Potash and phosphoric acid without lime. Yield per acre: good, 6,320 pounds; poor, 7,560 pounds.

Potash, phosphoric acid and nitrogen with lime. Yield per acre: good, 42,480 pounds; poor, 2,920 pounds.

B. Nitrogen with and without Lime.

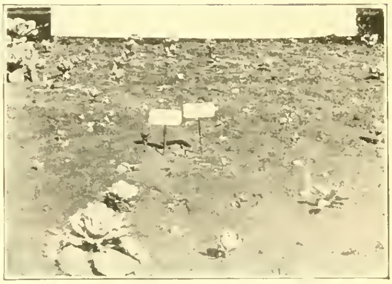
The lower left compared with upper right indicates the effect of nitrogen without lime: upper left compared with lower right the effect of nitrogen with lime.

PLATE II.

EFFECT OF ACIDULATED PHOSPHATE IN NEUTRALIZING THE EFFECT OF "SOIL ACIDITY."

CABBAGES, CROP OF 1917.

Nitrogen and phosphoric acid without lime. Yield per acre: good, 13,560 pounds; poor, 9,600 pounds.



Nitrogen and potash without lime. Yield per acre: good, 160 pounds; poor, 840 pounds. (An absolute crop failure.)

A. Without Lime.

The omission of phosphoric acid under acid soil conditions was fatal.

Nitrogen and phosphoric acid with lime. Yield per acre: good, 21,560 pounds; poor, 5,880 pounds.

Nitrogen and potash with lime. Yield per acre: good, 20,000 pounds; poor, 7,600 pounds.

B. With Lime.

A fair crop was produced without phosphoric acid, although, as shown on the opposite page, complete treatment gave much the larger crop.

same length of time. In both cases the crop was fairly satisfactory. On the other hand, nitrogen and phosphoric acid without lime gave an immensely larger crop than did nitrogen and potash without lime, — once again indicating that under certain conditions phosphorus functions in reducing need for lime, or in neutralizing the effects of soil acidity. It is also of interest to note that the yield of cabbages classified as "poor" is less absolutely, and very much less relatively, on the high-yielding plots than on the low-yielding plots.

General Summary.

The more important conclusions which may be drawn from this work, in their application to the fertility practice of Massachusetts farmers, are as follows: —

1. The kind of crop being grown and the cropping system followed determine the fertilizer needs of crops fully as much as does the soil type.

2. Where the soil is farmed without live stock, and no manure returned to the land, a complete fertilizer is more certain to bring satisfactory results than is any other fertilizer treatment.

3. The nitrogen response of crops is affected by nearness in the rotation to a legume crop, and likewise by the kind of crop. The tests indicate that where corn is grown either the first or second year following a legume, the use of fertilizer nitrogen does not bring anything more than a moderate return. The character of the season does not seem to have a dominant influence on the functioning of this plant food when applied in artificial form.

4. Where the whole crop is removed and manure not returned to the soil, large returns from the use of potash may be expected. As a corollary, the greater the extent to which crops are removed, the greater relatively will be the need for fertilizer potash; and on the other hand, the greater the extent to which crops produced are fed on the farm and manure returned, the lower will be the need for this plant food. The lesson therefore applies most particularly to farms where the supply of manure is deficient, and particularly to those where hay is cut for market, or where tobacco, onions or other money crops are raised continuously on the same land.

5. The use of lime in the cropping system followed has increased very significantly the size of crops. Apparently, however, it has had no effect on the availability of soil potash.

6. The tests show the great dependence of clover on a generous supply of lime, potash and phosphoric acid. They demonstrate a principle which is believed to be of almost universal application.

7. Soluble phosphates function in reducing, although not in eliminating, the crop damage caused by "acidity" or lack of lime.

8. Crops vary enormously in their response to the different plant foods. Except for corn and for grass and clover, however, the number of tests on individual crops is too small to permit of safe generalization.

APPENDIX.

Table I. — *South Soil Test (Yields per Acre).*

Year.	Crop.		Plot 1, Nitrate of Soda.	Plot 2, Dissolved Boneblack.	Plot 3, Check.	Plot 4, Muriate of Potash.	Plot 5, Lime.	Plot 6, Check.	Plot 7, Manure.	Plot 8, Nitrate and Boneblack.	Plot 9, Check.	Plot 10, Nitrate and Muriate.	Plot 11, Boneblack and Muriate.	Plot 12, Check.	Plot 13, Plaster.	Plot 14, Nitrate, Boneblack and Muriate.
1889	Corn	Grain (bushels)	31.25	30.00	24.75	49.25	30.75	23.50	57.50	37.00	36.75	53.00	58.00	32.50	31.25	61.50
		Stover (pounds)	1,660	1,940	1,440	2,980	1,740	1,400	4,200	2,100	2,080	3,020	3,960	2,100	1,880	4,180
1890	Corn	Grain (bushels)	45.60	49.50	43.75	62.60	51.80	45.56	59.75	50.37	42.50	53.94	65.90	52.20	52.00	71.00
		Stover (pounds)	3,750	3,590	4,850	4,590	3,660	3,500	5,520	3,260	3,130	4,235	4,880	3,525	3,540	5,320
1891	Oats	Grain (bushels)	33.13	18.13	18.13	24.07	24.69	20.31	38.44	29.07	16.56	29.69	25.94	17.50	15.94	33.13
		Straw (pounds)	2,500	1,490	1,490	1,750	1,300	1,400	4,620	2,210	1,260	2,270	1,630	1,350	1,240	3,010
1892	Grass and clover	Hay (pounds)	1,920	960	1,160	1,160	1,020	780	2,960	2,060	2,460	2,060	2,560	1,200	960	2,860
		Rowen (pounds)	720	800	640	1,400	720	600	2,240	640	660	1,040	1,900	840	680	1,340
1893	Grass and clover	Hay (pounds)	2,260	1,070	1,000	1,380	1,020	920	3,640	2,080	720	2,440	1,440	780	520	2,600
		Rowen pounds)	520	360	330	950	400	380	2,240	520	460	840	1,680	480	480	1,340
1894	Corn	Grain (bushels)	22.5	18.3	21.5	41.7	18.4	13.0	54.7	20.9	29.2	44.6	49.5	16.7	23.7	51.0
		Stover (pounds)	2,860	2,300	2,280	3,600	2,500	1,780	3,760	1,840	2,460	4,100	3,820	1,620	2,740	3,780
1895	Rye	Grain (bushels)	15.36	11.79	11.43	16.06	13.21	13.21	34.28	12.68	12.50	11.78	15.00	11.07	13.21	26.45
		Straw (pounds)	2,000	1,900	1,700	2,160	1,900	1,880	5,080	2,040	1,740	1,920	2,420	1,480	1,820	3,960
1896	Soy beans	Beans (bushels)	2.4	4.8	5.5	13.1	2.4	4.1	30.4	5.2	7.6	14.1	15.5	6.9	5.5	22.1
		Straw (pounds)	680	800	890	1,000	540	720	4,600	790	780	940	1,040	640	900	1,480
1897	Mustard (pounds)		–	–	–	–	20	–	8,500	900	–	–	500	–	–	5,100
1898	Corn	Grain (bushels)	20.6	18.5	9.8	19.8	10.4	16.9	67.7	32.0	12.5	10.9	41.2	10.5	21.9	55.9
		Stover (pounds)	2,210	1,400	1,050	1,540	1,000	1,100	3,800	1,700	800	1,300	2,440	650	1,300	2,600
1899	Corn	Grain (bushels)	13.7	3.5	3.9	49.7	7.2	5.0	75.9	21.4	5.9	47.9	59.9	3.6	6.6	72.9
		Stover (pounds)	1,160	620	730	2,760	1,100	820	5,350	1,220	840	2,360	3,160	680	990	4,450

1900	Grass and clover	Hay (pounds)	2,460	1,000	800	1,140	880	720	4,160	2,540	1,100	3,000	1,600	1,100	900	2,300
1901	Grass and clover	Hay (pounds)	900	300	400	600	500	300	3,600	1,200	400	2,100	1,900	400	200	3,300
		Rowen (pounds)	550	370	240	700	360	270	2,700	530	360	900	1,500	380	200	1,100
1902	Corn	Grain (bushels)	7.3	11.4	10.4	47.7	4.9	10.4	68.7	11.2	9.2	53.4	55.9	8.8	14.6	56.2
		Stover (pounds)	1,180	1,780	1,480	4,760	860	800	6,220	1,380	1,360	3,540	4,640	1,300	1,880	4,540
1903	Corn	Grain (bushels)	.56	.94	.94	16.61	.15	1.06	37.39	3.89	1.28	18.00	20.39	1.78	2.06	25.56
		Stover (pounds)	360	360	300	1,880	160	1,200	3,600	800	340	2,200	2,320	400	400	3,040
1904	Corn	Grain (bushels)	7.11	3.89	4.33	46.89	2.67	3.44	50.00	15.11	8.78	47.67	53.11	6.33	7.44	47.78
		Stover (pounds)	1,200	960	870	3,760	820	740	4,000	1,500	1,180	3,560	3,940	1,000	1,100	3,700
1905	Grass and clover	Hay (pounds)	2,600	400	600	2,100	1,000	700	3,200	2,000	1,200	1,500	2,300	1,400	700	1,700
1906	Grass and clover	Hay (pounds)	1,400	760	910	690	890	660	2,940	2,200	820	2,400	1,790	950	640	3,000
		Rowen (pounds)	520	295	300	440	260	325	2,670	520	390	470	1,220	410	320	1,100
1907	Corn	Grain (bushels)	1.00	.81	2.00	23.31	1.25	2.25	72.50	10.06	3.81	31.13	30.13	3.38	7.75	38.31
		Stover (pounds)	720	700	1,000	6,000	900	1,100	6,900	2,500	1,100	5,400	6,500	800	1,200	5,500
1908	Oats and crimson clover	Oat hay (pounds)	2,430	1,600	850	3,300	610	720	7,600	3,510	780	4,420	4,680	675	1,090	6,600
1909	Buckwheat (weight as cut, pounds)		5,808	2,299	3,388	6,897	3,872	4,054	16,214	7,744	4,235	10,043	9,922	3,993	4,840	14,036
1910	Corn	Grain (bushels)	14.28	5.57	3.86	24.65	5.07	9.21	57.43	8.93	4.57	26.72	37.14	17.21	13.86	41.57
		Stover (pounds)	1,700	1,800	400	2,120	500	1,100	3,700	1,900	700	2,200	2,300	1,700	800	3,080
1911	No crop		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1912	Crimson clover[1]		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1913	Corn	Grain (bushels)	22.6	11.0	11.7	52.6	8.7	8.4	66.8	–	–	51.2	49.7	29.1	11.0	44.4
		Stover (pounds)	2,420	2,180	2,240	4,360	2,460	1,700	5,140	–	–	3,500	4,040	2,740	1,880	3,840
1914	Soy beans (total weight, pounds)		3,500	900	1,000	6,000	1,200	1,800	11,500	–	–	9,100	7,700	1,700	1,700	9,800
1915	Corn	Grain (bushels)	22.86	10.00	8.50	40.86	5.29	10.93	60.79	–	–	34.25	37.58	16.5	10.92	35.15
		Stover (pounds)	1,490	760	615	1,980	635	720	3,520	–	–	3,365	3,250	960	805	3,400
1916	Sweet clover[1]		–	–	–	–	–	–	–	–	–	–	–	–	–	–
1917	Corn	Grain (bushels)	34.2	18.1	12.7	40.9	13.8	13.9	40.8	–	–	46.1	46.3	15.7	21.7	36.0
		Stover (pounds)	1,900	1,600	2,400	3,300	1,700	1,500	5,200	–	–	3,500	3,300	2,100	1,400	5,400
1918	Alfalfa	First cutting (pounds)	1,020	180	140	1,710	120	0	4,050	–	–	1,600	1,920	640	150	1,960
		Second cutting (pounds)	1,480	1,590	1,005	1,815	1,170	735	3,035	–	–	2,160	2,415	1,180	1,090	1,555

[1] No weights taken.

South Soil Test.

1889. An 8-rowed flint corn. 80 pounds per bushel.

1890. An early dent corn. 80 pounds per bushel.

1891. Variety, Early Race Horse. There was sown with the oats the following mixture of grass and clover: timothy, 12 pounds; redtop, 8 pounds; red clover, 6 pounds; white clover, 2 pounds; alsike clover, 3 pounds.

1894. Pride of the North. 80 pounds per bushel.

1895. After rye, the land was plowed and sown to white mustard, without additional fertilizer (July 31). Germination was quick and even, but except on the plots where manure or phosphate, lime and plaster have been applied, there was almost absolutely no growth.

1896. Medium Green. A wet fall. Beans not ripened well. Plots 1, 2, 5, 6 and 8 molded a little in stack.

1897. Unfavorable weather conditions destroyed the onions and cabbages. Sowed mustard August 14. Only four plots furnished sufficient growth to cut and weigh. Double application of manure and fertilizer made.

1898. Pride of the North. 80 pounds per bushel. On July 29 mustard was sown, covering plots and division strips. The mustard came up on all plots, but made no growth except on Plots 7 and 14, and even here was very spindling and light.

1899. Pride of the North. 80 pounds per bushel. Ears and leaves eaten by cows for 1 rod on the north end of Plot 7. Weights of stover on the best plots low because the corn, making a normal growth, was ripe long before it was cut and the stover became dry. Except on Plots 4, 7, 10, 11 and 14, the ears were very poor, immature and small.

1900. Spring sowing: awnless brome, 20 pounds; tall oat, 5 pounds; Italian rye, 8 pounds; meadow fescue, 8 pounds; orchard, 8 pounds; yellow oat, 5 pounds; medium red clover, 16 pounds.

1901. Hay; no clover except where potash has been applied. Brome grass most abundant on lime plots.

1902. From 1902 on the application of lime and plaster is at the rate of 40 pounds per plot instead of 20 pounds as heretofore.

1902. Pride of the North. 90 pounds per bushel. Corn weighed two weeks after husking. Stover varies greatly as to moisture.

1903. Pride of the North. 90 pounds per bushel. Stover well dried out.

1904. Pride of the North. 90 pounds per bushel.

1905. Spring sowing: timothy, 18 pounds; redtop, 8 pounds; meadow oat, 6 pounds; Italian rye, 8 pounds; awnless brome, 6 pounds; orchard, 15 pounds; mammoth red clover, 5 pounds; alsike, 4 pounds.

1907. Rustler white dent. 80 pounds per bushel. Weighed after drying out in glasshouse.

1908. Lincoln oats. A part of the oats on Plot 8, measuring 602 square feet, has been destroyed by Mr. Fitts' hens. Correction for same is made in the record of the yield.

Crimson clover, poor, plowed under.

1909. Product of a strip 10 feet wide across plots. The rest plowed under. Weighed as cut. Winter vetch and rye sown on September 30.

1910. 70 pounds per bushel. Fertilizer for Plot 11 probably applied to Plot 12 by mistake. Sowed alsike clover in corn, August 2.

1911. No crop. Flint Laboratory takes Plots 8 and 9. Fertilizer applied as usual, field plowed and kept cultivated and free from weeds.

1912. Crimson clover, poor, no crop.

1913. Rustler white dent. 70 pounds per bushel. Weighed after being dried in glasshouse.

1914. Medium Green. Did not mature.

1915. Longfellow. 70 pounds per bushel.

1916. Sweet clover. Mostly weeds; cut and removed without weighing.

1917. Sweet clover plowed under.

Corn, Early Canada Flint. Plot 12 received about one-half the fertilizer for Plot 11. This amount was made up on Plot 11. 70 pounds per bushel.

1918. Alfalfa, sown Aug. 20, 1917, in corn. Second cutting, Plots 2, 3, 5, 12 and 13 mostly grass and weeds; Plot 6 all grass and weeds.

TABLE II. — *Precipitation in Inches.*

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1889 . .	3.29	1.45	1.46	2.42	4.71	5.01	10.52	2.72	3.17	4.58	6.04	3.57	48.94
1890 . .	2.61	4.20	5.37	1.73	5.39	1.53	5.63	4.88	5.85	7.13	1.32	2.86	48.5 0
1891 . .	6.75	4.23	2.99	2.66	1.97	4.75	5.28	4.18	2.66	2.94	2.99	5.40	46.80
1892 . .	5.85	1.90	2.40	0.76	6.28	3.46	4.41	6.47	2.16	0.66	4.98	1.01	40.34
1893 . .	3.33	5.75	3.66	4.41	5.02	3.32	2.59	3.49	2.82	4.88	2.81	4.86	46.94
1894 . .	2.16	1.74	1.77	1.83	4.00	3.13	1.55	0.31	4.63	4.85	3.14	3.53	32.64
1895 . .	3.87	1.05	2.71	5.56	2.07	2.76	3.87	3.46	5.04	4.77	5.36	3.94	44.46
1896 . .	1.07	4.67	6.11	1.32	2.58	2.57	4.96	3.84	5.41	3.23	3.03	0.87	39.66
1897 . .	3.00	2.52	3.53	2.42	4.38	6.65	14.51	4.29	1.94	0.73	5.85	7.23	57.05
1898 . .	7.15	3.80	1.63	3.73	5.61	3.69	4.09	6.85	3.65	6.27	5.48	2.30	54.25
1899 . .	2.80	3.56	7.13	1.79	1.28	4.13	4.89	2.00	7.90	1.84	2.17	2.00	41.49
1900 . .	4.08	8.12	5.76	1.85	3.78	3.65	4.67	4.11	3.67	3.72	5.87	2.40	51.68
1901 . .	1.81	0.62	5.66	5.95	6.91	0.87	3.86	6.14	4.17	3.88	2.08	7.77	49.72
1902 . .	1.72	3.54	5.29	3.31	2.32	4.54	4.66	4.65	5.83	5.59	1.27	4.27	46.99
1903 . .	3.28	4.27	6.40	2.30	0.48	7.79	4.64	4.92	1.66	2.72	2.04	3.95	44.45
1904 . .	4.74	2.45	4.48	5.73	4.55	5.35	2.62	4.09	5.45	1.74	1.35	2.75	45.30
1905 . .	3.90	1.70	3.66	2.56	1.28	2.86	2.63	6.47	6.26	2.27	2.06	3.15	38.80
1906 . .	2.18	2.73	4.90	3.25	4.95	2.82	3.45	6.42	2.59	5.69	1.98	4.49	45.45
1907 . .	2.73	1.92	1.82	1.98	4.02	2.36	3.87	1.44	8.74	5.00	4.50	3.89	42.27
1908 . .	2.25	3.53	2.86	1.97	4.35	0.76	3.28	4.27	1.73	1.57	1.06	3.05	30.68
1909 . .	3.56	5.16	3.01	5.53	3.36	2.24	2.24	3.79	4.99	1.23	1.06	2.95	39.12
1910 . .	6.14	5.08	1.37	3.07	2.67	2.65	1.90	4.03	2.86	0.93	3.69	1.72	36.11
1911 . .	2.36	2.18	3.80	1.87	1.37	2.02	4.21	5.92	3.41	8.81	3.84	4.42	44.21
1912 . .	2.18	3.16	5.70	3.92	4.34	0.77	2.61	3.22	2.52	2.07	4.03	4.04	38.56
1913 . .	3.98	2.94	6.38	3.30	4.94	0.90	1.59	2.26	2.56	5.16	2.11	3.38	39.50
1914 . .	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	0.52	2.09	2.62	2.89	41.83
1915 . .	6.52	7.02	0.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916 . .	2.56	5.27	3.97	3.69	3.21	5.34	6.85	2.49	5.08	1.01	3.29	2.85	45.61
1917 . .	3.64	1.98	4.08	1.83	4.13	5.27	3.36	7.06	2.42	6.60	0.63	2.56	43.56
1918 . .	4.11	2.99	2.91	2.78	2.47	4.01	1.84	2.22	7.00	1.32	2.87	2.95	37.47
1919 . .	2.02	2.80	4.22	2.37	6.20	1.09	4.17	4.81	4.25	1.81	6.20	1.48	41.42
1920 . .	2.74	4.45	3.63	4.71	3.65	6.26	2.06	3.62	6.74	1.54	5.62	6.02	51.04
1921 . .	2.00	2.38	3.57	6.47	4.56	3.87	6.00	2.35	1.84	1.08	6.20	1.90	42.22

Table III. — *Temperature and Frost Records.*

Year.	Mean Hourly Temperature (Degrees Fahrenheit).						Last Spring Frost.	First Fall Frost.
	April.	May.	June.	July.	August.	September		
1889	49.3	61.4	67.7	69.5	65.5	61.9	May 26	Sept. 21
1890	46.5	57.1	65.3	69.8	67.2	59.7	May 12	Sept. 25
1891	49.4	57.3	66.6	68.2	70.2	65.3	May 19	Oct. 12
1892	48.7	56.1	70.3	72.2	70.0	60.6	May 10	Sept. 30
1893	44.7	58.7	69.0	71.4	71.0	58.1	May 8	Sept. 3
1894	47.9	58.7	69.4	73.5	69.3	64.8	May 22	Aug. 22
1895	46.9	61.3	70.5	69.3	70.4	63.8	May 17	Aug. 22
1896	49.2	62.4	65.0	70.7	68.2	59.2	May 1	Sept. 24
1897	46.5	57.1	61.8	70.5	66.0	59.8	May 8	Sept. 22
1898	43.0	55.6	66.0	70.9	69.7	63.0	April 27	Sept. 21
1899	46.1	55.7	67.4	70.1	68.0	59.7	May 4	Sept. 14
1900	46.9	55.4	67.1	70.6	70.1	63.8	May 29	Sept. 15
1901	46.8	56.2	68.0	72.5	69.9	62.1	May 6	Sept. 26
1902	47.3	57.0	63.5	67.8	66.1	60.3	May 14	Sept. 6
1903	46.9	59.2	59.6	68.9	62.0	61.3	May 2	Sept. 25
1904	42.5	60.1	65.0	69.8	66.4	59.8	April 23	Sept. 22
1905	45.6	56.9	64.4	71.1	65.8	59.1	May 24	Sept. 12
1906	45.1	56.7	66.1	70.1	70.5	64.0	May 20	Sept. 25
1907	41.5	51.8	63.9	70.0	66.1	61.3	May 22	Sept. 27
1908	45.1	59.2	67.6	72.5	66.6	62.9	June 3	Sept. 16
1909	44.4	55.5	66.4	68.7	66.5	60.5	May 12	Oct. 13
1910	50.6	56.1	63.8	72.1	67.1	61.1	May 6	Sept. 23
1911	43.7	61.9	64.5	73.7	67.8	60.2	May 5	Sept. 14
1912	45.2	58.1	65.0	71.6	66.4	61.2	May 1	Aug. 31
1913	47.6	55.6	66.4	71.4	69.5	59.7	May 15	Sept. 10
1914	42.1	59.0	64.4	67.7	68.9	60.2	May 16	Sept. 28
1915	49.9	54.1	64.2	68.9	66.0	64.2	May 20	Sept. 23
1916	43.9	55.9	61.1	71.6	69.5	60.8	May 19	Sept. 17
1917	42.9	49.3	65.3	71.7	70.9	57.0	May 18	Sept. 11
1918	45.7	62.1	62.9	70.1	70.5	57.6	April 26	Sept. 11
1919	45.4	57.6	68.4	71.8	65.8	61.7	May 1	Sept. 18
1920	43.2	54.6	64.5	68.3	70.2	62.8	April 26	Oct. 7
1921	51.5	58.9	66.9	73.4	66.9	65.6	May 12	Oct. 9

TABLE IV. — *North Soil Test (Yields per Acre).*

Year.	Crop.		Plot 1, Check.	Plot 2, Nitrate of Soda.	Plot 3, Dissolved Boneblack.	Plot 4, Check.	Plot 5, Muriate.	Plot 6, Nitrate and Boneblack.	Plot 7, Nitrate and Muriate.	Plot 8, Check.	Plot 9, Bone-black and Muriate.	Plot 10, Nitrate, Boneblack and Muriate.	Plot 11, Plaster.	Plot 12, Check.
1890	Corn	Grain (bushels)	51.2	53.3	57.5	51.3	69.3	59.4	67.6	48.1	74.0	74.9	51.5	47.5
		Stover (pounds)	5,620	5,700	4,340	4,190	5,740	4,330	5,430	3,890	5,740	5,820	4,240	4,180
1891	Potatoes	Large (bushels)	25.67	26.33	35.67	17.33	63.33	32.33	61.33	16.67	49.33	58.33	15.67	11.67
		Small (bushels)	4.33	4.67	5.67	5.67	4.00	6.33	5.00	2.67	3.33	6.33	6.67	6.00
1892	Soy beans	Beans (bushels)	12.83	13.67	10.33	11.75	15.42	13.00	16.08	13.08	12.92	13.67	13.17	12.67
		Straw (pounds)	1,000	920	940	1,040	1,110	1,200	1,100	960	900	960	960	1,100
1893	Oats	Grain (bushels)	48.13	42.19	41.56	43.75	52.19	45.94	49.69	42.81	47.50	46.56	41.25	42.81
		Straw (pounds)	1,920	1,880	1,760	1,700	2,220	2,660	2,680	1,900	2,760	2,920	1,720	1,940
1891	Grass and clover	Hay (pounds)	640	1,320	680	280	240	1,500	680	200	440	1,620	360	220
1895	Grass and clover	Hay (pounds)	1,000	1,000	640	660	1,200	1,310	1,680	640	920	1,860	620	820
		Rowen (pounds)	–	–	–	–	340	–	–	–	220	200	–	–
1896	Cabbage	Hard (pounds)	1,200	3,240	2,080	2,640	10,520	12,000	5,800	3,800	21,200	26,200	3,320	2,240
		Soft (pounds)	9,680	8,680	8,600	8,900	7,480	9,080	4,200	6,880	7,400	6,680	6,600	4,200
1896	Turnips (pounds)		14,400	12,400	9,800	9,800	10,200	14,000	14,000	9,800	21,200	23,000	8,000	7,000
1897	Potatoes	Large (bushels)	15.50	8.87	22.00	30.00	42.00	88.33	29.67	20.67	54.00	55.33	35.83	38.00
		Small (bushels)	52.00	35.67	32.00	28.17	35.50	33.00	38.83	38.67	30.67	38.50	23.00	26.50
1898	Onions	Tops and bulbs (pounds)	940	830	1,640	1,310	1,540	9,640	650	920	2,100	4,360	680	1,540
		Merchantable (bushels)	.8	2.5	5.2	1.2	.8	116.8	.2	.8	1.9	16.3	.5	1.1
1899	Onions	Sound (bushels), unlimed	2.69	18.65	6.53	5.19	3.07	143.10	3.07	2.88[1]	40.38[1]	46.15[1]	4.04[1]	4.04
		Sound (bushels), limed	4.42	91.43	12.31	26.15	161.75[1]	145.40	200.00[1]	16.93[1]	183.80	224.60	6.35[1]	30.39[1]
1900	Onions	Sound (bushels), unlimed	6.15	50.00	17.31	72.69	37.69	225.77	9.23	38.46	159.62	136.92	4.62	23.46
		Sound (bushels), limed	41.54	155.00	37.69	132.31	383.46	202.31	310.77	107.69	380.00	488.46	23.08	102.31
1901	Onions	Tops and bulbs (pounds), unlimed	1,680	2,400	1,880	1,400	3,000	8,800	2,400	800	10,000	18,600	1,400	1,400
		Tops and bulbs (pounds), limed	3,200	4,200	2,600	2,200	11,200	8,000	13,800	2,480	13,200	22,600	2,960	2,720

[1] Uncertainty as to accuracy, as the labels were accidentally moved.

TABLE IV. — *North Soil Test (Yields per Acre)* — Concluded.

Year.	Crop.		Plot 1, Check.	Plot 2, Nitrate of Soda.	Plot 3, Dissolved Boneblack.	Plot 4, Check.	Plot 5, Muriate.	Plot 6, Nitrate and Boneblack.	Plot 7, Nitrate and Muriate.	Plot 8, Check.	Plot 9, Boneblack and Muriate.	Plot 10, Nitrate, Boneblack and Muriate.	Plot 11, Plaster.	Plot 12, Check.
1902	Potatoes	Large (bushels), unlimed	27.7	30.0	39.3	31.3	58.0	69.3	51.3	35.3	73.7	110.3	24.7	24.5
		Small (bushels)	24.0	20.7	20.0	22.7	15.3	28.7	26.0	29.3	18.0	17.0	16.0	21.7
		Large (bushels), limed	21.3	27.3	26.0	22.7	69.0	71.3	58.3	32.7	93.7	115.3	24.3	30.3
		Small (bushels)	27.7	20.3	22.0	21.3	12.7	29.0	17.3	21.3	20.0	17.3	13.7	17.3
1903	Grass and clover	Hay (pounds), unlimed	360	1,520	950	550	660	1,830	1,820	450	620	2,330	430	420
		Hay (pounds), limed	1,150	3,140	1,560	1,010	950	3,180	2,190	570	920	2,830	480	1,140
1904	Grass and clover	Hay (pounds), unlimed	1,060	1,960	1,000	560	600	2,120	1,920	560	860	2,200	560	640
		Rowen (pounds)	140	60	60	30	70	210	50	40	80	620	20	10
		Hay (pounds), limed	800	1,600	680	560	1,920	2,320	1,860	940	3,600	4,400	600	1,280
		Rowen (pounds)	80	90	120	130	780	810	520	500	2,560	2,840	80	240
1905	Corn	Grain (bushels), unlimed	8.71	13.88	7.76	5.41	5.65	20.24	12.47	4.47	11.29	36.24	10.59	16.00
		Stover (pounds)	3,100	480	3,400	3,160	4,040	3,600	2,960	1,800	4,520	5,840	2,240	3,140
		Grain (bushels), limed	7.88	9.06	5.88	8.94	18.35	29.18	29.53	18.12	34 24	43.06	19.53	20.00
		Stover (pounds)	2,520	3,960	2,640	2,920	4,400	3,680	3,720	3,520	3,400	4,840	2,320	2,280
1906	Soy beans	Beans (bushels), unlimed	10.86	4.48	5.52	13.1	8.28	6.90	9.66	7.76	6.90	7.93	5.34	10.34
		Straw (pounds),	690	440	380	630	520	520	740	600	420	400	400	720
		Beans (bushels), limed	5.17	3.45	3.97	6.72	12.41	9.48	14.14	8.79	10.34	14.14	6.03	9.83
		Straw (pounds)	430	490	400	500	720	760	780	520	600	920	400	560
1907	Grass and clover[1]		–	–	–	–	–	–	–	–	–	–	–	–
1908	Grass and clover	Hay (pounds), unlimed	1,340	3,280	940	780	860	3,720	3,240	480	800	4,240	320	440
		Hay (pounds), limed	2,160	3,880	1,600	1,560	2,380	4,600	3,800	1,640	3,240	4,730	1,580	2,220
1909	Grass and clover	Hay (pounds), unlimed	1,280	1,980	1,260	1,180	1,050	2,010	1,240	1,150	920	1,790	380	720
		Hay (pounds), limed	1,570	1,780	1,420	1,520	3,640	2,760	2,980	1,560	3,840	2,520	1,180	1,520
1910	Soy beans	Beans (bushels), unlimed	15.86	14.83	11.38	12.41	8.97	14.48	8.28	9.66	4.83	8.28	10.00	10.34
		Straw (pounds)	1,680	3,140	2,680	1,580	1,680	2,160	1,520	1,840	1,040	2,200	1,300	1,400
		Beans (bushels), limed	20.00	19.31	13.79	17.59	24.83	18.62	18.97	19.31	19.66	16.55	14.48	13.79
		Straw (pounds)	2,920	3,480	2,800	3,180	1,560	4,120	1,820	3,360	1,460	3,240	2,480	3,480

1911	Soy beans	Beans (bushels), unlimed	10.00	4.66	4.66	10.34	14.48	10.86	14.48	10.86	14.31	17.07	8.28	11.05
		Straw (pounds)	1,820	1,450	1,530	1,920	2,160	2,290	2,360	1,890	3,370	3,610	1,320	1,760
		Beans (bushels), limed	1.03	2.07	.86	2.59	20.34	6.90	20.69	15.52	15.86	20.17	1.38	6.21
		Straw (pounds)	940	1,480	950	1,450	2,820	2,600	3,000	3,100	2,880	3,830	1,920	2,640
1912	Soy beans[2]		–	–	–	–	–	–	–	–	–	–	–	–
1913	Rye	Grain (bushels), unlimed	33.6	30.7	29.6	30.4	28.9	27.9	22.9	16.0	17.1	21.8	15.4	16.4
		Straw (pounds)	5,040	4,060	3,860	4,080	4,380	4,240	4,720	2,900	3,640	3,780	3,140	2,880
		Grain (bushels), limed	33.9	36.4	28.9	33.2	35.3	35.3	35.3	30.7	31.1	35.7	35.7	37.9
		Straw (pounds)	5,200	6,220	5,180	3,940	5,220	5,020	5,620	5,080	5,260	5,600	6,000	6,080
1914	Grass and clover	Hay (pounds), unlimed	1,600	2,020	1,490	1,240	1,280	2,540	2,000	820	1,030	2,600	860	600
		Rowen (pounds)	–	–	–	–	–	–	–	–	–	–	–	–
		Hay (pounds), limed	1,840	2,870	1,680	1,830	4,140	3,800	3,080	2,320	3,620	5,310	2,400	2,980
		Rowen (pounds)	–	–	–	200	1,400	40	1,000	600	800	800	200	80
1915	Grass and clover	Hay (pounds), unlimed	920	1,440	1,180	1,020	1,580	1,280	960	520	580	900	460	480
		Rowen (pounds)	–	–	–	–	–	–	–	–	–	–	–	–
		Hay (pounds), limed	1,260	1,400	1,200	1,400	3,700	3,500	3,800	1,600	3,600	4,200	1,100	2,300
		Rowen (pounds)	220	180	180	820	3,050	690	1,760	720	1,620	1,600	280	640
1916	Corn	Grain (bushels), unlimed	21.3	34.5	35.1	28.8	25.9	43.3	25.1	16.3	30.3	38.3	19.9	14.5
		Stover (pounds)	1,600	2,200	3,000	2,600	3,000	3,600	2,900	1,400	2,500	4,200	2,000	1,200
		Grain (bushels), limed	18.7	19.7	21.7	31.5	36.9	41.3	45.7	31.9	48.1	51.2	27.9	26.4
		Stover (pounds)	1,200	1,600	1,600	2,000	2,600	2,800	3,800	2,400	4,000	4,200	2,000	1,600
1917	Cabbage	Good (pounds), unlimed	240	880	2,560	100	180	13,560	160	160	6,320	26,040	720	–
		Poor (pounds)	1,760	2,200	7,240	920	1,400	9,600	840	1,240	7,560	7,320	6,240	1,040
		Good (pounds), limed	10,120	13,640	2,980	7,240	15,360	21,560	20,400	9,320	25,000	42,480	3,980	7,520
		Poor (pounds)	10,160	9,600	6,240	9,240	7,320	5,880	7,600	10,560	7,720	2,920	9,320	9,480
1918	Beans	Total weight (pounds), unlimed	1,460	1,240	960	1,780	2,320	1,980	2,380	1,960	1,680	2,500	1,000	1,520
		Total weight (pounds), limed	960	960	800	1,180	3,840	2,200	4,360	1,180	3,040	3,740	200	700
1919	Hungarian[3]		–	–	–	–	–	–	–	–	–	–	–	–
1920	Rye[4]		–	–	–	–	–	–	–	–	–	–	–	–
1921	Rye	Grain (bushels), unlimed	10.4	10.0	11.8	7.5	10.4	16.4	10.0	9.3	9.6	7.5	4.6	7.3
		Straw (pounds)	1,280	1,240	1,490	960	1,320	960	1,240	940	1,300	800	520	860
		Grain (bushels), limed	15.2	11.8	12.1	14.3	15.5	15.7	13.9	12.1	6.1	7.1	11.1	10.7
		Straw (pounds)	1,680	1,340	1,340	1,480	1,820	1,760	1,440	1,600	2,360	1,280	1,480	1,300

[1] No weights.
[2] Plowed under.
[3] Not harvested.
[4] Spring seeded; not harvested.

North Soil Test.

Plot 11.—Plaster, 160 pounds per acre until 1896. In 1896 increased to 400 pounds per acre. In 1902 increased to 800 pounds per acre.

Lime. — The west half of the field has been limed four times as follows: —

1899, 1 ton per acre air-slaked lime.
1904, about 1 ton per acre air-slaked lime.
1907, ½ ton per acre lime.
1916, about 2 tons per acre limestone.

1890. Variety an early dent. Sown in drills, thinned to 6 inches in the row. Cut, stooked and husked instead of being put into the silo as planned. 75 pounds per bushel.

1891. Variety, Beauty of Hebron, seed from Aroostook County, Me. Sprouted unevenly, leaving many vacant places about equally divided among the plots. Somewhat injured by frost.

1892. 60 pounds per bushel.

1893. Plots 3, 6 and 10 lodged badly; 1, 4, 5, 7, 8 and 12 stand fairly well; 5, 7 and 12 quite green; 6, 9, 10 well matured. Fall seeded: timothy, 20 pounds; redtop, 10 pounds; red clover, 6 pounds; alsike, 4 pounds.

1894. Seeded Nov. 29, 1893. Few flower stalks showing when cut. No clover. As weighed from the field the difference in the degree of dryness was quite noticeable.

1895. Hay, mostly redtop except little clover on Plots 10, 9, 7 and 5.

1896. Cabbage on west half and turnips on east half. Turnips rather poor stand, probably weighed tops and roots together.

1897. Fertilizer doubled. Potatoes under 2 ounces called "small."

1898. Fertilizer doubled.

1899. Fertilizer doubled. First liming of west half.

1900. Fertilizer doubled. Field has washed quite badly diagonally. Plot 1 washed some this summer while crop was in. Fall seeded to oats.

1901. Fertilizer doubled. Fall seeded to rye.

1902. Fertilizer doubled. Potatoes, variety, Delaware. Fall seeded: timothy, 18 pounds; redtop, 8 pounds; red clover, 5 pounds; alsike, 4 pounds.

1903. April 4: sow 15 pounds red clover. July 20: the only clover is on limed halves of Plots 9 and 10. Fertilizer doubled

1904. Fertilizer doubled. Second liming of west half. Limed half: hay, very little timothy except on Plot 10; very little redtop on Plots 9 and 10; mostly clover on Plots 5, 9 and 10. Unlimed half: hay, almost no timothy; 50 per cent or over redtop; very little clover on Plots 1, 2, 3, 4, 7, 8 and 12.

1905. Fertilizer back to normal. Sibley's Pride of the North. Total yield at 85 pounds per bushel.

1906. Medium Green. Rather a poor stand.

1907. Spring seeded, 4½ pounds mixed timothy, redtop and clover per plot. Crop mostly weeds; no weights. Third liming of west half.

1908. Mostly redtop. Small amount of clover on Plots 5 and 9, both limed and unlimed. Very little timothy on any plots.

1910. Medium Early Yellow.

1911. Medium Early Yellow.

1912. Medium Yellow soy beans; very poor stand. Plowed under and seeded to rye.

1913. Fall seeded: timothy, 20 pounds; redtop, 10 pounds; red clover, 5 pounds; alsike, 5 pounds.

1914. Rowen practically all clover.

1915. Hay. Unlimed: 1, 2, 3, 4, 11 and 12 mostly all grass; 10 half grass and half clover; 5 mostly all clover; 6, 7, 8 and 9 some clover. Limed: 2, 3 and 6 mostly all grass; 2 and 3 mostly all redtop; 1, 4, 8, 11 and 12 half grass and half clover; 5, 7, 9 and 10 mostly clover.

1916. Longfellow Corn. Fourth liming.

1917. Danish Ballhead.

1918. Yellow Eye Bean. Very unsatisfactory growth. Total weights taken as harvested. Fall seeded to rye.

1919. Plot 1 used for barium-phosphate test. Hungarian on rest of field, not harvested.

1920. Spring seeded to rye. Plowed and fall seeded to rye. No fertilizer applied.

1921. No fertilizer applied.

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